THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

THE INSTITUTION OF

PRODUCTION ENGINEERS JOURNAL

10 CHESTERFIELD STREET . LONDON . W1 Telephone: GROsvenor 5254/9

Vol. 34, No. 5 *Price 10/-* *May 1955*

CONTENTS

"Education and Research for Production" by K. J. Hume, B.Sc., M.I.Mech.E., M.I.Prod.E. 261

"The Basic Nomenclature of Cutting Tools" by George V. Stabler, B.Sc., M.I.Mech.E., M.I.Prod.E., M.I.E.I. 264

"The Significance of Machine Tools in The Australian Economy" by H. Grafton, Dipl.Ing., A.M.I.E.(Aust.), A.M.I.Mech.E., A.M.I.Prod.E. 280

"The Practical Uses of Electronics in Industry" by K. A. Zandstra, A.M.I.E.E. 288

"Training in Work Study, with detailed reference to the Case Study Method in Applied Work Study" by John Purcell, A.M.I.Prod.E. 305

"Ultrasonic Tools for Hard-to-Machine Materials" by J. P. Aloisio and N. Clark, Jr. 315

Notice of Council Elections, 1955/56 320

Institution Notes 321

News of Members 322

Hazleton Memorial Library—Reviews and Additions 323

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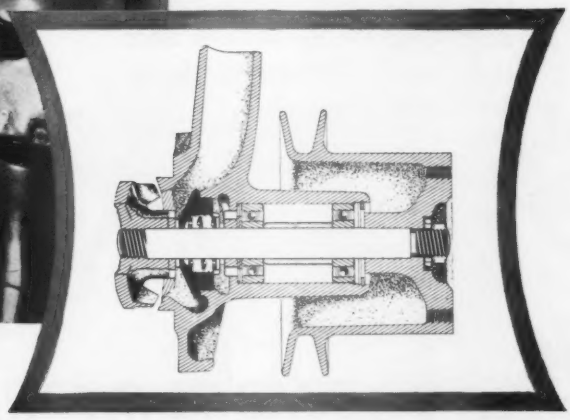

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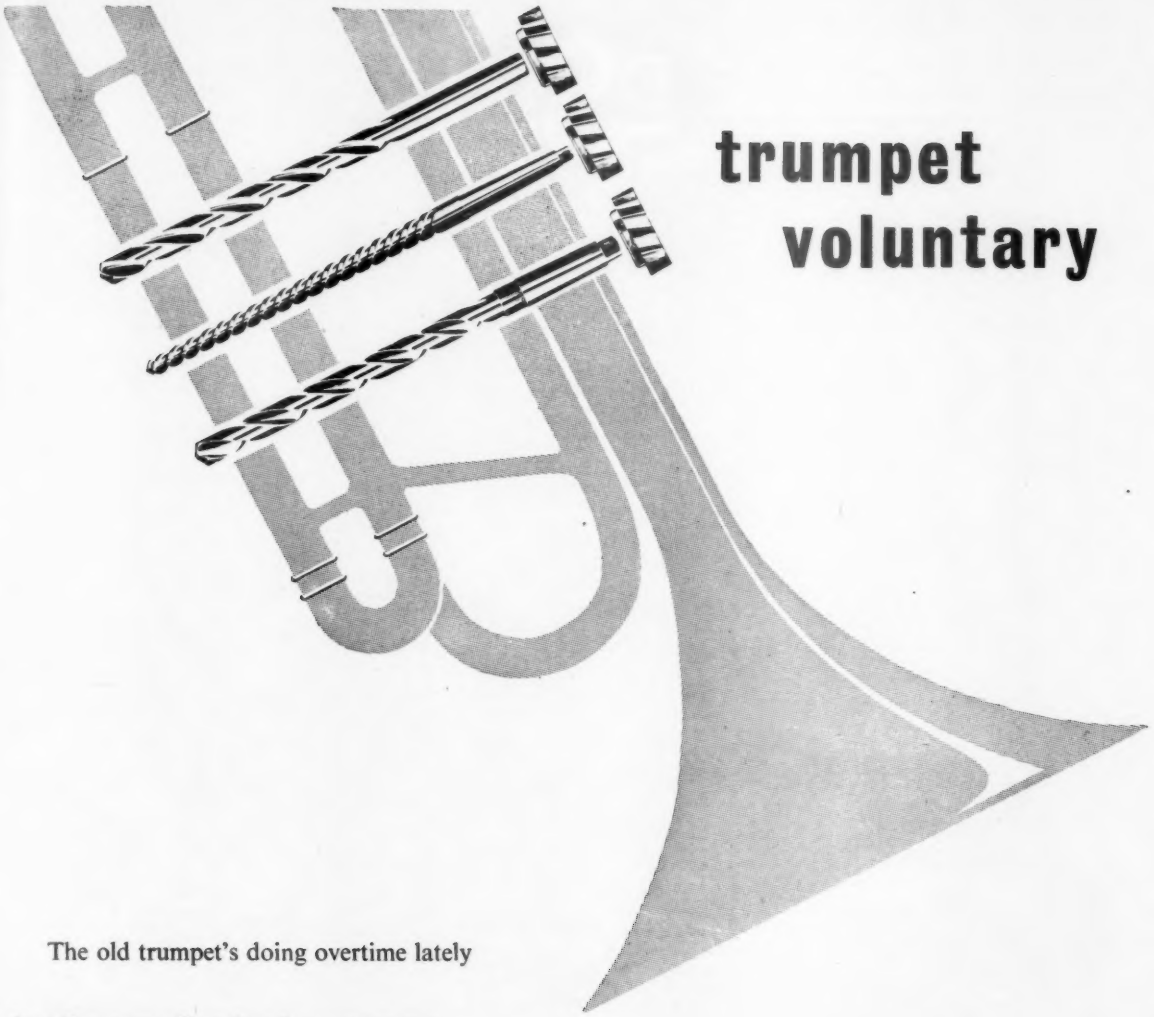

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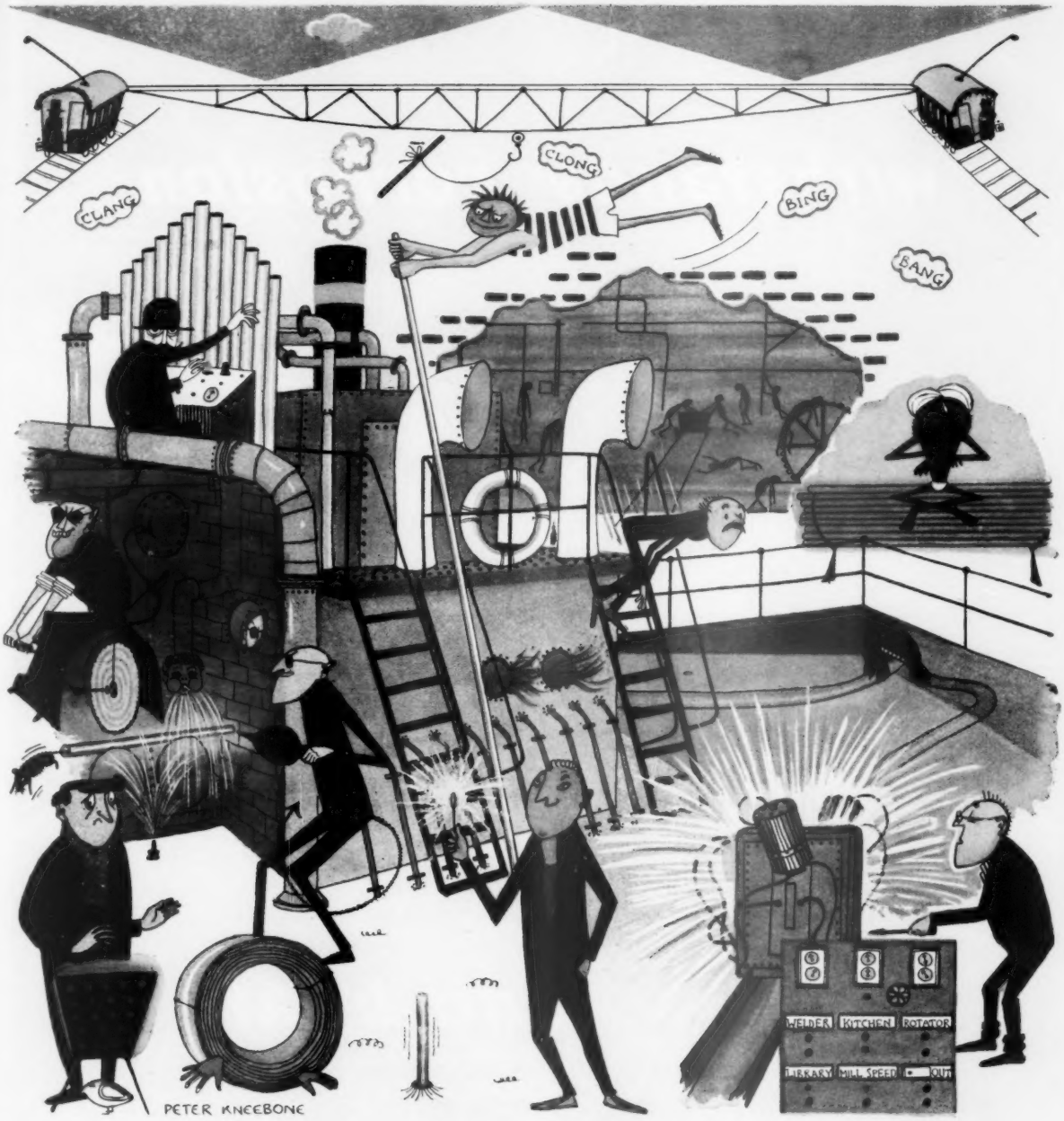

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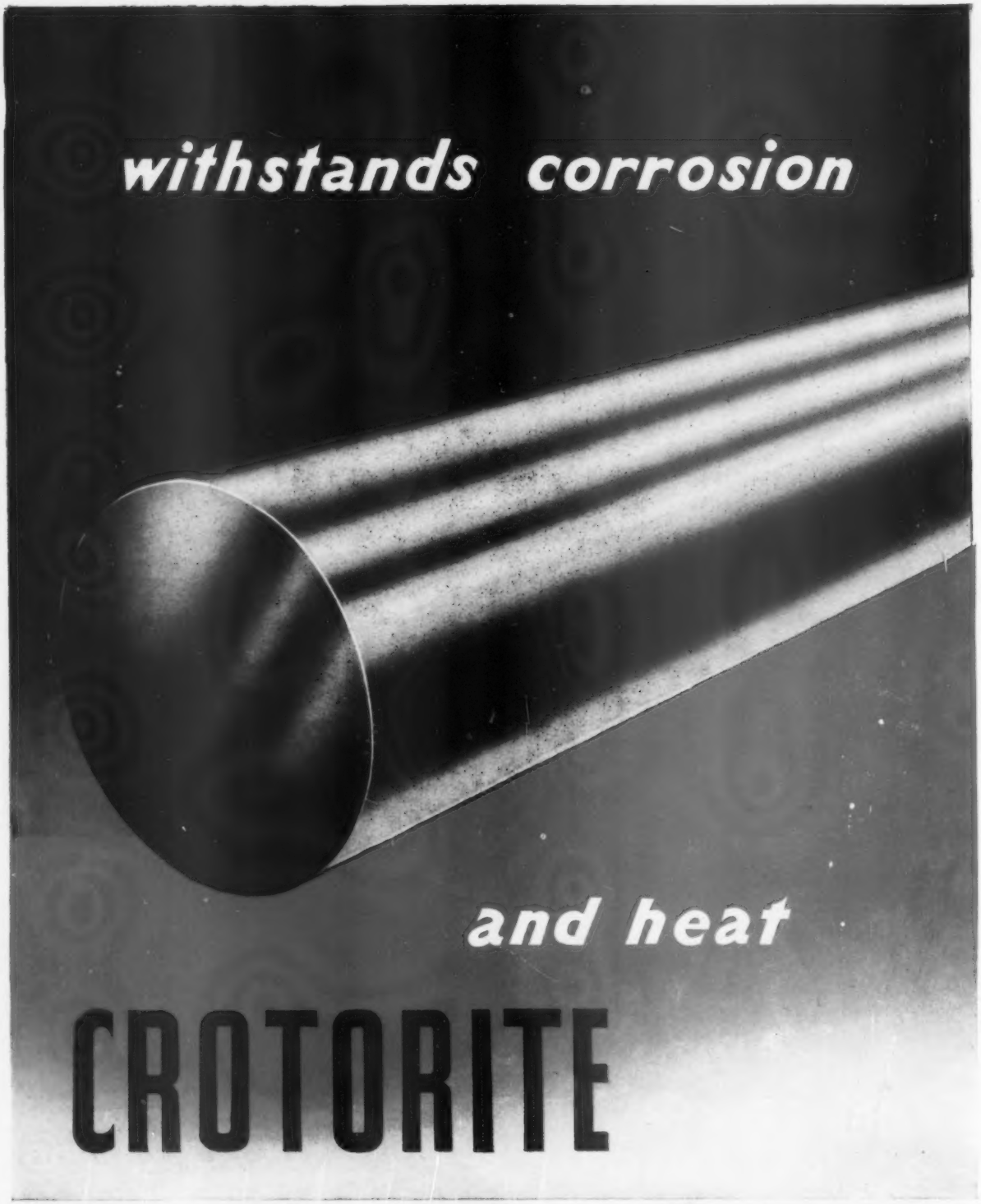

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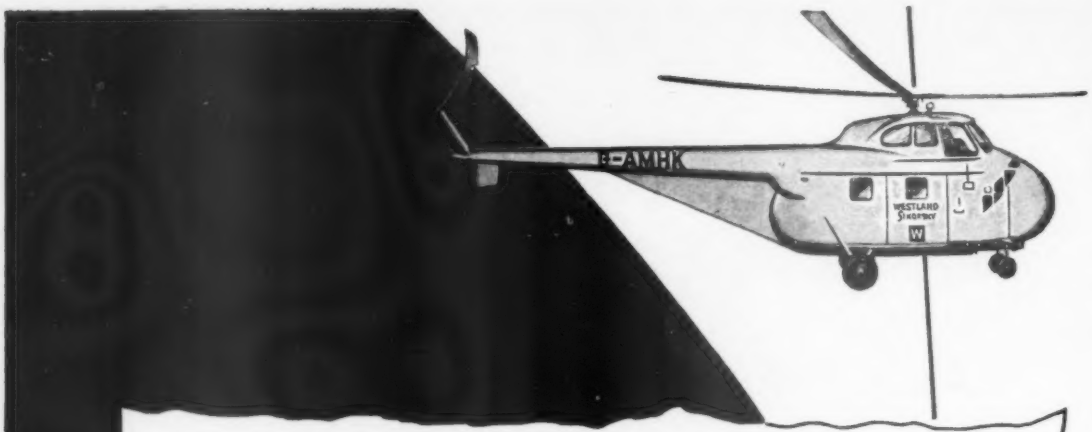

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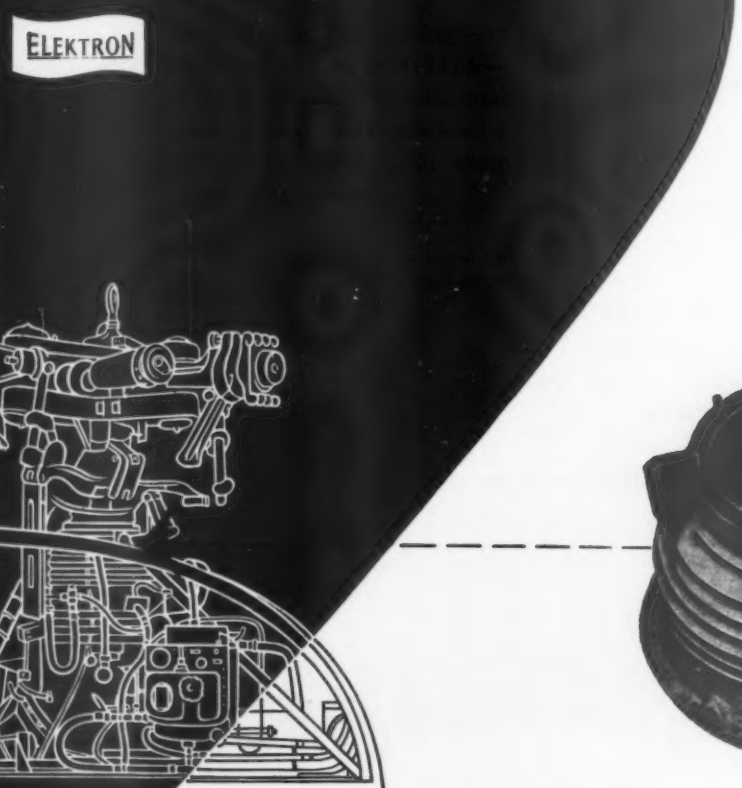

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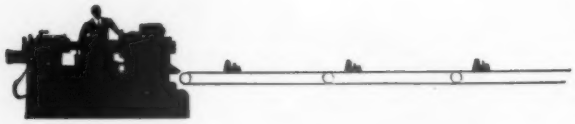

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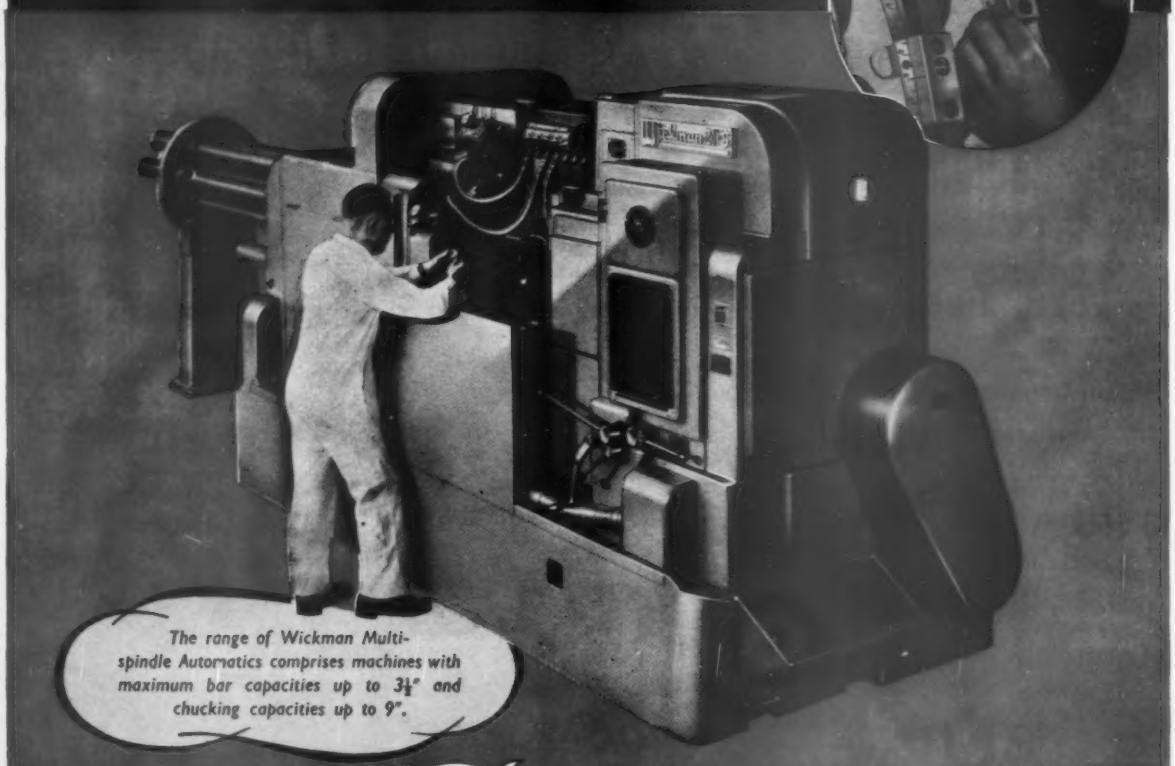

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The Institution of Production Engineers Journal
VOL. 34 NO. 5 MAY, 1955

Education and Research for Production

by K. J. HUME, B.Sc., M.I.Mech.E., M.I.Prod.E.
Head of The National College of Horology & Instrument Technology; Chairman of the Institution's Papers Committee.

This article, which concludes the present series, summarises the views expressed by earlier contributors and underlines the importance of the subject under discussion.

READERS of the earlier articles in this series cannot have failed to notice that most of the writers appeared to be much more concerned with problems of education rather than research. It does not require a very profound knowledge of the technological industries of today to realise that there is an acute shortage of skilled and trained personnel in all of them. The advertisement columns, and even display advertising space, of the national, local and technical press are pathetic evidence of the intense, and often futile, competition which exists among the industrial giants and Government departments for the very few qualified people who are in, or can be persuaded to come into, the labour market.

Even Sir Ben Lockspeiser's authoritative comments on research turn on the supply of technologists who are concerned with design, production and management, with a plea for more appropriate training at all levels. It is significant that he is not pressing so much for research staffs as for properly educated production personnel who are able to make the best use of the results of research. Without such people, the results of research would end with the presentation of papers to learned societies and could be soon forgotten, except by other research workers in similar fields.

We have by no means reached this position and it is unthinkable that we should ever do so, but it is a fact that much valuable discovery and invention takes far too long before it is developed and applied to production.

Realistic Training

A thought which runs through several of the previous articles is that too much attention must not be paid to any one level of education or individual technical achievement. Professor Wright Baker emphasises the importance of the academic middle man, holding the average honours degree or Higher National Certificate. He warns us, however, of the increasing complexity and pace of technology which will demand from young engineers more ability to think and assess. His well-known arguments for a realistic adjustment of syllabuses should be heeded. Much of the traditional work which is carried on in many of our teaching laboratories and workshops still continues simply because it *is* traditional. Some syllabuses in workshop technology seem to take no account of the fact that time is both limited and precious. How many hours are spent by apprentices in doing complicated filing exercises before they are allowed to touch anything else ?

One might sometimes think that these early days were the only opportunity ever likely to be available to practise such techniques. Without advocating for a moment the acceptance of second-best results in the final outcome, it is quite practicable to arrange a programme of work which keeps the beginner moving on to different operations while his interest is maintained, although he will naturally not attain perfection in the initial stages. If subsequent parts of the programme are sufficiently varied, he should get ample opportunity to perfect his techniques. The standard of acceptance of his work must obviously be gradually advanced to ensure that improvments are, in fact, being made.

Policy of Promotion

For many years, grumblings have been heard from production managers that apprentice schemes tend to lift too many young men from the level of operatives and craftsmen to 'white collar' categories. The implication is that they 'get ideas above their station' and should not be encouraged too strongly to develop to the maximum of their abilities. The same sort of attitude can be seen throughout industry, as well as in other spheres, where promotion or transfer of individuals to more responsible posts is sometimes opposed (albeit secretly) because these people are too useful in the jobs they are doing and would be difficult to replace. Sir Walter Puckey has illustrated this by calling for more 'one-ulcer men' to attempt 'two-ulcer jobs'. It is often true of many organisations that one must leave to achieve any advancement or improved prospects.

There is danger too in the other extreme, where too many senior executives have spent the whole of their careers in the one organisation. Ironically enough, this sometimes occurs in firms who have first class training organisations. Young men who make good in the technical school find themselves making rapid headway, particularly if the firm is young and expanding; this can lead to a form of inbreeding which tends to stifle the introduction of new ideas. There was much to be said for the old principle of turning out every apprentice at the end of his time to gain experience elsewhere. This would be rather risky under present conditions, but it is probable that much more could be done in this way if the principle were generally agreed and acted on in industry.

Engineering as a Career

Sir Walter Puckey has also pointed out that shortage of manpower and the recruitment of the right types of young people are problems which are not confined to the technological industries. He warns us that the complete solution is not to be found by taking men from other spheres where they are also badly needed.

This is sound advice, but are there not many spheres which, by tradition, take some of the country's best brains and do not make the best use of them ? This idea may sound horribly materialistic and soulless, particularly to the classical scholars, who make a pretence of horror at any learning which directly provides the tools of a livelihood. As Lord Hives points out, it is time to explode the old myth that a classical education is the only one which will give a man the highest outlook on life. Wide reading and an appreciation of the arts are essentials in the making of a good engineer but it is ridiculous to suggest that the study of natural sciences, which are the basis of all engineering, is less noble than, say, the study of ancient Greek.

A great deal of prejudice has to be overcome in many schools and universities to gain acceptance for the idea that science and engineering are honourable professions which can provide an individual with just as full a life as the older professions. What works manager would not agree that more can be learnt of humanity, in its broadest sense, in the everyday problems of industry than in all the text books of ancient history and dead languages ?

The experiment, related by Lord Hives, of putting Arts graduates through an engineering works course designed for engineers, shows that it is the men themselves who are the important factor, the precise education they may have received being of less importance. Mr. G. R. Pryor, our present Chairman of Council, has also emphasised the importance of human qualities, particularly the quality of leadership. Detailed and specialised technical knowledge will always be required in many engineers and is undoubtedly difficult to find in sufficient quantity, but the less tangible qualities of leadership, foresight, judgment and temperament are even more thinly spread among those who need them.

Relationship of Research and Education

The present article, no less than some of the earlier ones, appears to have come down heavily on the side of education and to have neglected research. This fault is, perhaps, more apparent than real. On what does successful research depend ? It certainly needs finance, buildings and equipment, and today, more money than ever before is being willingly allocated by industry and governments alike to the needs of research. But, in the end, its greatest need is the right type of personnel, including those who are actually doing the work and those who are providing the moral and material backing.

Research for production therefore has the same fundamental needs as education for production. It has long been established that, in science, education without research does not make progress. True research in the field of production engineering is not easily defined, partly because the whole subject is comparatively new. The divisions between research, development and mere trial and error are also obscure, perhaps because of the pace of industry and the many complex factors, including human ones, which beset the problems to be solved.

Research and the Institution

It was not many years ago that the first independent organisation for production engineering research was established in this country under the auspices of this Institution. A considerable amount of good work was done, initially under the direction of the late Dr. Schlesinger. In those early days, the greatest obstacle to expansion was finance; representations were made for D.S.I.R. assistance but, under existing regulations, this could not be obtained until independent finance reached a certain level. This level could only be reached by substantial contributions from industry and, eventually, the organisation now known as P.E.R.A. was born.

The good work started by the Institution has been continued on an even larger scale, and P.E.R.A. has become one of the most important research associations in the country. It has solved many problems for member firms, and the direct savings obtained in improved production are very substantial. In addition to its own experimental work, the Association offers to members an extensive reference and abstracting service, which makes available much more published material than any one firm is likely to have at its own command.

This aspect of research is just as important as direct experimental work and it is often surprising to discover the extent to which other people have had to face the same problems as oneself.

Although the Institution has handed over to P.E.R.A. the responsibility for production research, a number of senior members of the Institution serve on the Council of P.E.R.A. and on its Committees. It is important that there should be the closest co-operation between the two bodies.

The Institution and Education

The function of the Institution in education is well recognised and can be more clearly defined. It is our responsibility, both through official functions and through individual members, to see that education in production engineering proceeds along the right lines, learning by experience and making adjustments to suit changing conditions. A vital principle to be remembered by everyone is that education is not restricted to the classroom or to those who are undergoing formal training. No one is too old, too busy or to important to learn.

THE BASIC NOMENCLATURE OF CUTTING TOOLS

by GEORGE V. STABLER, B.Sc., M.I.Mech.E., M.I.Prod.E., M.I.E.I.

Presented to the Glasgow Section of the Institution, November, 1954.

After serving an apprenticeship at Messrs. Robert Stephenson & Co. Ltd., Locomotive Builders, Darlington, Mr. Stabler went to Armstrong College, (now King's) University of Durham, where he graduated in 1927 with an Honours Degree in Mechanical Engineering.

He served for five years as an Assistant Engineer in the Indian Stores Department, Government of India, being stationed in Calcutta and Bombay.

After teaching academic subjects at Darlington Technical College for a year, he went to Northampton Polytechnic, London, where he took part in a major development of Production Engineering teaching. Between 1939 and 1946 he was Lecturer in Charge of Workshop Classes at Coventry Technical College.

For over eight years Mr. Stabler has been Senior Lecturer in Production Engineering at the Royal Technical College, Glasgow.

Mr. Stabler

CUTTING tool nomenclature was born in the workshop. It slowly grew into the present state of great confusion, an unkempt child, fiercely fought over by workman, production engineer and scientist alike. Men in the workshops have so far received very little assistance in this field from the advances made in understanding cutting action, with the result that the old arguments about the effect of this or that angle still go on with unabated vigour. Production engineers still follow the shop methods and are handicapped in solving some of the many practical problems they have to face by the use of terms which themselves confuse the issue. Uncontrolled common usage has resulted in a number of different names for the same thing on different varieties of tools, until the already complex subject of metal cutting is bogged down in unnecessary confusion. The great advances made in tool research have been handicapped by rival nomenclatures which have resulted in apparently conflicting results which sometimes really agree. The salesman is enabled to exploit the situation by making all kinds of claims and as he himself is somewhat in the dark, and as few are in a position to challenge him, his claims go unquestioned. Even such agreement as has been reached has resulted in at least three national specifications which differ from each other, and within each nation the arguments still rage. Teachers or instructors have the difficult task of presenting information to their students and of teaching them to think and to use their knowledge. They can only succeed by concentrating on fundamentals and their applications to practical problems. In cutting tool nomenclature they are not assisted by the present terms or by the available literature. A certain modern book (Ref 1) spends 214 pages in thirteen chapters in describing eleven separate angles of a single point tool without once touching on the simple basic facts.

The situation is like that which Shakespeare contemplated when he wrote :-

> *" O misery on't—the wise gods seel our eyes:*
> *In our own filth drop our clear judgements: make us*
> *Adore our errors: laugh at's while we strut*
> *To our confusion"*

It is easy to understand how the original rule of thumb methods in the shop and the early lack of knowledge of the fundamentals of cutting action led to the present confusion. It is now possible to take the seal from our eyes if we wish. The time has now arrived when it is at last possible to make a marked advance and this Paper is put forward with the object of clarifying the situation.

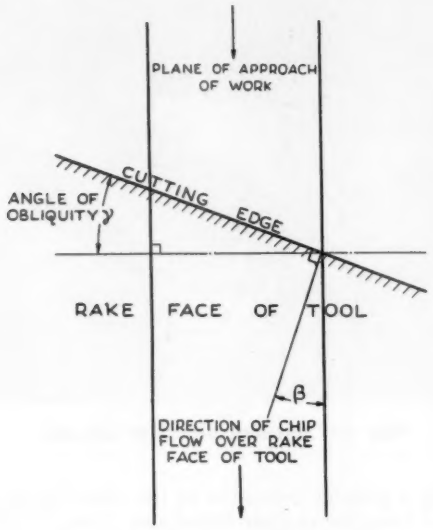

PLANE OF APPROACH OF WORK
CUTTING EDGE
ANGLE OF OBLIQUITY γ
RAKE FACE OF TOOL
β
DIRECTION OF CHIP FLOW OVER RAKE FACE OF TOOL

Fig. 1. Chip flow diagram.

The Flow Law

Since 1946 the Author has had the opportunity, at the Royal Technical College, Glasgow, of doing research work on cutting tools in order to resolve some of the more puzzling problems accumulated during forty years' continuous contact with machine shops. About 1949 a simple universal law of chip flow was discovered and after extensive testing under all kinds of conditions, its geometrical and theoretical implications were worked out and published in 1951 (Ref. 2). At the time the full implications of the law on tool nomenclature were not realised, but further thought and research work have emphasised the importance of the discovery.

The flow law, technically expressed as $\beta = \gamma$ may be stated as follows :- " Metal chips flow over the rake face of a tool at the same angle as the metal approached the cutting edge."

This astonishingly simple law is easy to appreciate and to observe in the workshop, once it is understood properly. It is well known that metal approaching an edge at right angles moves off at right angles, this illustrating a particular example of the law at zero obliquity. Let the metal approach at any other angle to the normal, or alternatively let the edge itself have an angle of obliquity to the direction of approach, then the chip will deviate from the normal by just that same angle if it is measured in the plane of the rake face. The flow is unaffected by the rake angle, however defined and measured, a fact which has delayed the discovery of the law until recently. Altering the rake alters the direction of chip flow with reference to the tool shank or machine, but does not affect the flow on the tool face. It is very simple to prove that the initial flow direction is unaffected by such things as cutting speed, material being cut, depth of cut or feed. Some of these

Fig. 2. Single point tool.

factors occasionally obscure the initial flow—speed for instance affects the degree of curling. The only known exception to the law is where two adjacent cutting edges join and the natural flow is interfered with, a matter which is touched on later. Fig. 1 shows a diagrammatic representation of the flow law. For the purposes of the diagram the rake face of the tool has been imagined as hinged at the cutting edge and moved through an angle equal to 90° minus the rake angle, so that it is in the same plane as the approach of the work.

Fig. 2 shows a large scale model of a single point tool with a primary rake of 15°, plan angle of 20° and Fig. 3 its 20° angle of obliquity. Fig. 4 shows a strip of perspex cut at 20° at its end and placed on the cutting edge. The perspex represents a chip of any metal giving continuous flow being cut at any speed or feed.

An appreciation of the flow law is of considerable practical assistance to tool designers. Once the effect of possible variations of speed of chip flow at different parts of the cutting edge is grasped, the behaviour of the chip in all types of cutting operations may be

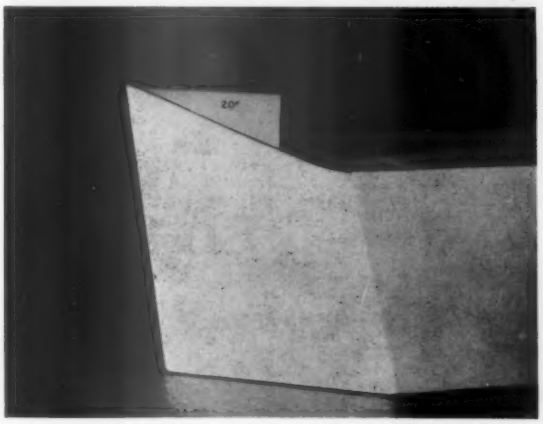


Fig. 3. Angle of obliquity of single point tool.

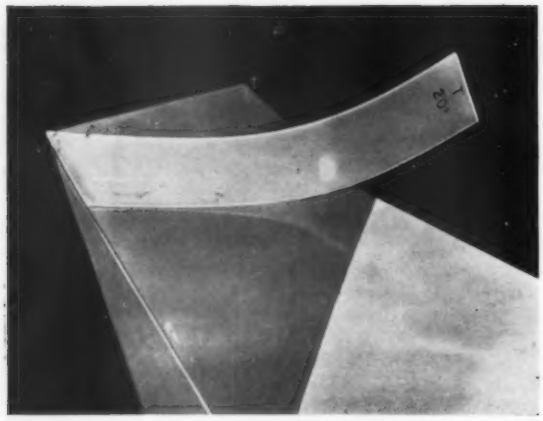


Fig. 4. Chip flow in single point tool.

Fig. 6. American back and side rake.

predicted. This will help in the disposal of swarf, in the designing of chip breakers, and in arranging that the chips are prevented from damaging the finished surface.

Existing Nomenclature Systems

British

In 1952 the British Standards Association published B.S.1886 for single point tools and the "English" system of maximum rake was adopted. This method measures rake in a vertical plane in the direction of the maximum slope of the rake face. The method is shown in Fig. 5, the maximum rake for this tool being 25°, and in the horizontal plane it is at 52° to the primary cutting edge.

The method gives the mathematical angle between the rake face and the base of the tool, a fact which is of no practical value because it has no relation to the position of the cutting edge, to the life of the tool, to its efficiency or to the direction of chip flow. It follows a vague practice of the manufacturers in giving a general indication of the direction of slope of the rake face in their catalogues. It is of little use in the workshops and it is not much used by the men. The flow law was discovered during an attempt to prove that the chip flowed in the direction of the steepest slope, a theory that was conclusively proved to be false. The angle alone does not specify the rake plane with regard to the cutting edge and its relationship to the tool or work has to be specified by another angle.

It is difficult to see any sound justification, practical or theoretical, for the adoption of this system.

Fig. 5. British maximum rake.

American

The American system (A.S.A.) is to specify the rake in two of the orthogonal planes of the tool, the measurement being made from the third or base plane. The method is shown in Fig. 6, the side rake for the condition shown being 8° and the back rake 24°.

These terms have the merit of being readily understood and because they specify the rake plane with relation to the tool shank they are of some assistance in tool grinding. The system is in common use in British workshops and is "included" in B.S.1886.

The resolution of the rake of the tool into two directions confuses the appreciation of the effect of that rake on the cutting action. As in the British system there is no regard to the position of the cutting edge and the plan angle has to be specified before the real cutting conditions are settled, and even then a mathematician is required to sort out the resulting complications. If the two rakes remain fixed in a given tool so fixing the rake plane, quite a variety of cutting conditions can be obtained by varying the plan angle. The method treats the rake of the leading or primary edge in precisely the same way as that of the trailing or secondary edge, yet the two edges are obviously different in cutting action. If a tool grinder thinks in terms of side and back rake only, the chip flow and other important features of the cutting are not apparent and are very liable to be left to chance.

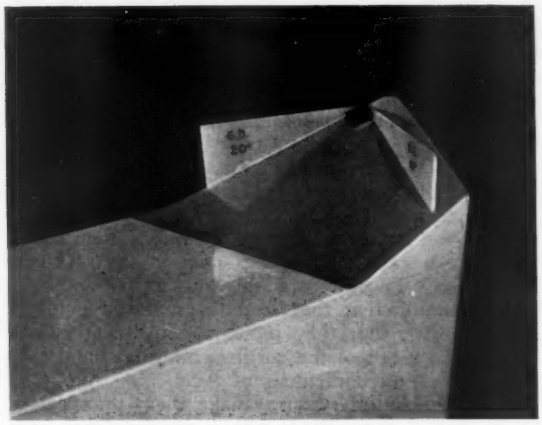


Fig. 7. German back and side rake.

Fig. 8. Primary rake.

German

The German (D.I.N.) system specifies two rakes in vertical orthogonal planes, one, the ' cutting edge side rake ' in a plane at right angles to the plan angle, the second parallel to the plan angle. The system is shown in Fig. 7, the side rake for the conditions shown being 20° and the back rake 16°.

The system is a distinct step ahead of the other two systems because it comes much nearer to the real tool-work relationship. It has the merit of being easy to measure, the rake being in the same plane as the true clearance. It was devised long before the flow law was discovered, yet its "back rake" is the obliquity of the cutting edge and is, therefore, an exact measure of chip flow. Its side rake, however, is a function of the back rake, any change in the obliquity altering the side rake (see Ref. 2, Eq. 1). It cannot, therefore, be a true fundamental or a practical guide to the cutting conditions.

The German side rake is called ' true ' rake in America and the term has appeared in high grade research papers by Merchant and Kronenburg and others. There is, in fact, no ' truth ' in the angle at all as regards chip flow, cutting force, life, surface finish, or any other factor, and the Author has suggested in Ref. 2, page 15, that its reference letter " t " be translated as ' tool ' with much more meaning. It is the angle of rake appearing on the end face of a spiral cylindrical milling cutter.

The Primary Rake

In his classical analysis of the mechanics of the metal cutting process, (Ref. 3), Merchant used the term " oblique rake " and used for its reference the first Greek letter alpha. It is the rake measured at right angles to the cutting edge and *at right angles to the rake face*. It is shown in Fig. 8, the dark squares indicating right angles, and the rake being 15°. The method of specification makes it very easy to recognise on any tool.

In ket. 2, the Author gave reasons for preferring the term ' primary ' rake, and subsequent thought and research has confirmed this preference. There can be no doubt that from the so-called ' theoretical ' standpoint, the primary rake is the only one worthy of consideration.

Thinking of the rake face as hinged on the cutting edge is of great assistance in appreciation of primary rake. If Fig. 1 were folded on the oblique line representing the cutting edge so that the top and bottom of the diagram were at right angles, zero rake would be shown. Any reasonable person would measure the deviation of the rake plane from that zero in only one way, and that way is the primary rake. This method of specifying rake is not only mathematical, but it is very highly practical.

Effective Rake

The chip flow law enables the exact change of direction of metal being cut to be found in terms of the obliquity and the primary rake only. In Ref . 2, the Author gave a clear definition of ' effective ' rake together with its trigonometric relationship with those two variables and easily read

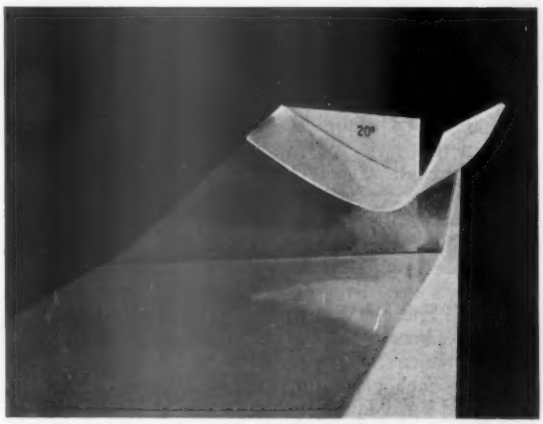


Fig. 9. Effective rake.

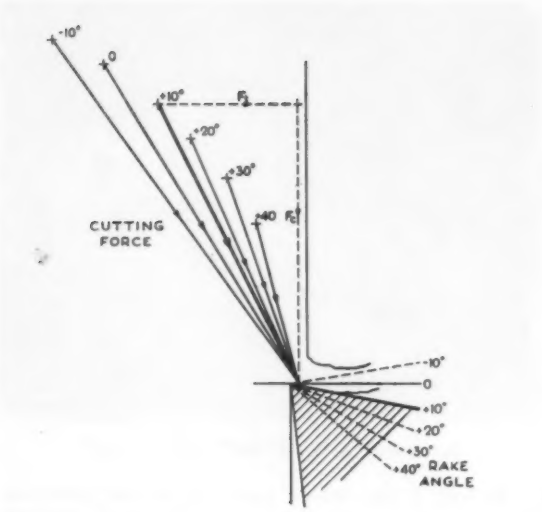


Fig. 10. Effect of primary rake on cutting force.

charts to find its value and the direction of flow with respect to the tool. The effective rake is shown in Fig. 9, the angle for the particular tool being 20°.

Rake is a geometric term meaning 'incline from the perpendicular' and if any of the many ways of specifying rake is to be called 'true', the effective rake must be regarded as the winning candidate. However, as it is only geometrically true and as research shows that it does not reflect any of the other important cutting factors, it is best to avoid the 'true' qualification.

The Case for Basic Simplicity

In the older sciences pioneers have long ago discovered many of the fundamental principles and after an initial period of questioning and of the overcoming of prejudices, they have been accepted as helpful guiding truths. Boyle's, Charles', Hooke's and Newton's laws are examples. Their adoption has simplified an enormous number of practical problems and the example of gravitation shows that it has not hindered further refinements or adjustments.

The ancient art of cutting metals is now in the process of becoming a science. From the great mass of research work that has been carried out it should be possible to find some of the basic principles. As a professional lecturer the Author has had continuous close contact with practical affairs in the workshop and has also studied the advanced research work. Theory and practice are not really two separate camps. Their different viewpoints should influence each other until the best interests of both are found on common ground.

As long ago as 1935, (Ref. 4) the Author questioned the use of such terms as 'side', 'back' and 'top' to qualify the rake angle, and he has for long sought the basic laws of tool nomenclature. The discovery of the flow law and the subsequent research on it was the key which led to the conviction that the primary rake and the obliquity were the only two basic angles in any cutting tool.

If these angles were difficult to understand or to recognise, if they were impracticable, if they were difficult to set up in the toolroom or if they did not indicate the important cutting conditions, then there, would be a case for keeping them in the scientists back room. The fact that they are simple and easy to understand, that they lead to great simplicity in tool grinding, that they indicate with great clarity the various facets of the cutting conditions, and that they resolve the difficulties of reconciling the three rival nomenclature systems, make them practical in the highest degree. Because they are basic they may be applied to any cutting tool with the advantage that the apparent complexity of the great variety of tools is made much more simple.

Research Work

Under the direction of the Author, ten theses on cutting tools have been written in the past few years by students of the Royal Technical College as part of their Associateship in Mechanical Engineering. Much of the later work was with the object of finding out which of the various methods of specifying rake was the basic one and what was the effect of obliquity. References 5 to 8 give the theses devoted to this work and as the results are far too voluminous for general publication, an extract of the main results is given here.

(a) *Primary rake and cutting force*

The magnitude and position of the cutting force on the tool as a function of the primary rake angles is shown in Fig. 10. No scale is shown because the actual values vary with the material being cut. The force may be resolved into a force, Fc, in the direction of cutting, and a force, Ft, a thrust force normal to it. It will be noticed that Ft is always positive and that there is no truth in the claim made in some sales literature that there is a change of sign when passing through the arbitrary zero. Practical experience shows that any tool has to be held up to its work to resist Ft.

A fixed vector is not a true representation of a cutting force because the cutting action produces rapid variations of magnitude and position whose degree is a function of many factors. If the rake is increased in metal cutting to the region of 50° or 60°, Ft becomes permanently or temporarily negative with the result that the tool digs in and an already short life is brought to a sudden end.

(b) *Primary rake and power consumption*

There is no motion in the direction of Ft, and, except for negligible effects, the force Fc is the only power consumer. Fig. 11 is a projection of the Fc in Fig. 10, on a base of primary rake. The height

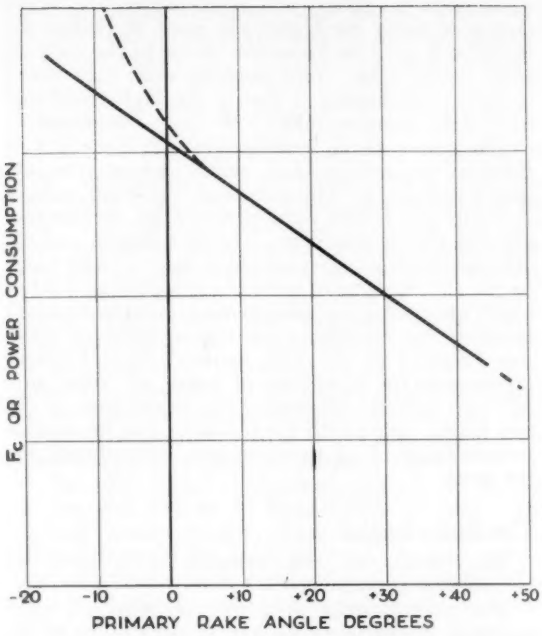


Fig. 11. Effect of primary rake on power consumption.

of the curve above zero and its slope are functions of the material being cut. The area between the straight line and the dotted curve at its upper end indicate a region of variable results which may be avoided by high cutting speed.

(c) *Obliquity and cutting force*

The introduction of obliquity alters the direction of the cutting force by an amount equal to about two thirds of the obliquity. It introduces a third component, Fl, a lateral force in the same plane as the cutting edge. There are theoretical indications which show that this lateral force increases almost uniformly with the obliquity. In Fig. 12, results

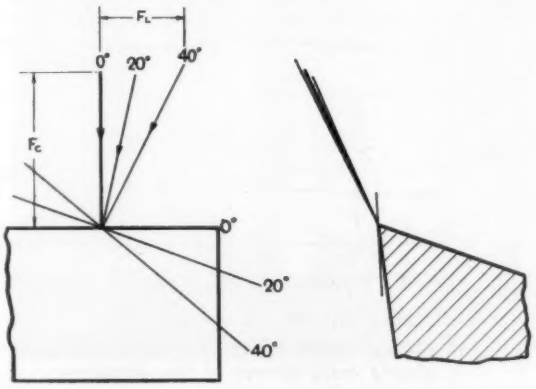


Fig. 12. Effect of obliquity on cutting force.

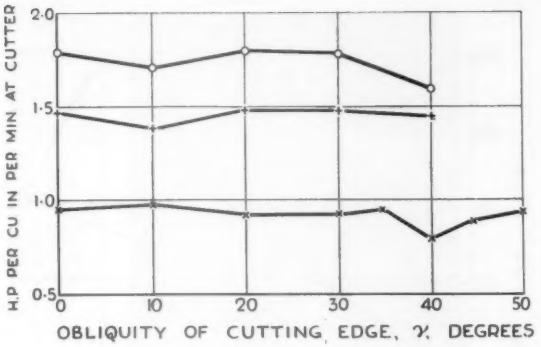


Fig. 13. Effect of obliquity on power consumption.

are shown of tests which confirm the theory and which show that, although obliquity increases the resultant cutting force, the force in the direction of cutting, Fc, the power consumption and the thrust force, Ft, are for all practical purposes left unaffected.

(d) *Obliquity and power consumption*

The effect of obliquity on power consumption, or Fc, is shown for both turning and milling in Fig. 13. Although the experimental conditions were difficult due to the necessity to have a single clear variable, the results show that, up to a range outside that normally met with in cutting tools, obliquity has no practical effect on power consumption. This is a valuable result because there are practical advantages to be obtained from oblique cutting edges, specially in taking up entry shocks and in controlling chip flow. The result also emphasises the basic nature of obliquity.

(e) *Tool life*

Tool life is of outstanding importance. The wear which makes regrinding necessary is itself complex and life may be measured in a number of different ways such as length and depth of clearance face wear, development of rake face crater, spalling or rounding of the cutting edge, and complete breakdown due to one or more of these factors. Much has already been done in investigating the curves of development of these different factors. The general characteristic is a short initial period of rapid wear, merging into a prolonged period of slower wear, followed by a final rapid breakdown.

The primary rake is the only method of measuring rake which is in direct proportion to the volume of metal available for the conductance of heat. The effects of rake in shortening tool life in orthogonal cutting have been extensively studied.

Obliquity should increase tool life because it brings

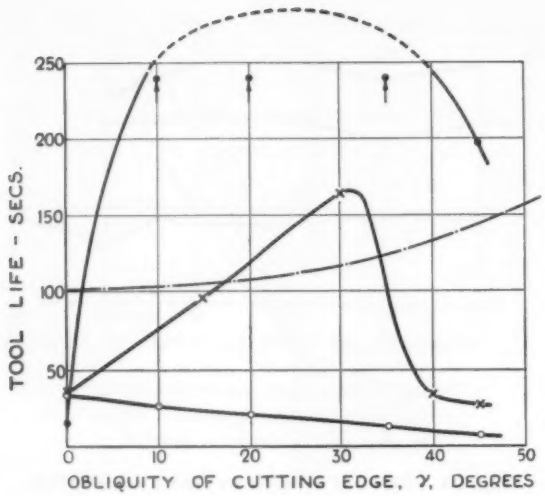


Fig. 14. Effect of obliquity on tool life.

in an additional length of edge and volume of metal to do the same amount of work. The effect, which is in proportion to the secant of the angle, is shown by the chain dotted curve in Fig. 14. The lower full curve in this figure shows the result of turning tool life tests in which the obliquity directed the chip in to the finished surface, an effect which increased with the angle. The tool failed on the nose radius and the shortening of life with obliquity is not surprising. The middle full curve is the result of giving the obliquity the opposite sense so as to direct the chip away from the work. The upper 'curve' shows the results of tests on the end of a tube so that a pure variable was obtained. The dotted portion is conjectural, the three tests shown by arrows having to be stopped when the tool had lasted four minutes without failure.

Long term tool life tests are expensive to make and short term ones under very arduous conditions may not always reveal normal conditions, due to transient heat conductance effects. The short term tests shown in Fig. 14 were inconclusive and the real effect of obliquity was obscured by other factors. Wear and life are so complex that it is probable that there is no fixed relationship between them and obliquity.

(f) *Surface finish*

The whole purpose of a cutting tool is to produce a surface with satisfactory geometric properties plus a satisfactory local surface texture. In orthogonal cutting the effects of primary rake on surface texture have been studied and are fairly well known. The effect varies with the type of cutting action of the material being cut and, except for such materials as brass and cast iron, increase of rake gives a better finish. In judging tool performance the cutting speed must be taken into consideration, the broad indication being the higher the speed the better the finish because of the reduction in size of the built up edge. The high finish possible with high speed negative rake cutting is due to the high speed and not to the negative rake.

The results of an investigation into the effect of obliquity on surface finish when cutting brass are shown in Fig. 15. The tests were also done on mild steel but the results were obscured by the harmful effect of the built up edge. The tests showed that the obliquity had no practical effect over a wide range on the C.L.A. value of the surface produced, a result which persisted if the measurements were made along or across the direction of cutting or along or across the direction of the tool marks. Fig. 16 shows photographs of a surface of brass cut with zero, 32° and 52° of obliquity. The orientation of the tool marks varied with the obliquity, but the surface texture value of all three surfaces was substantially the same.

The Basic Angles

The results of this research work may be summarised as follows :-

The primary rake of a tool measured at right angles to the cutting edge and at right angles to the rake face controls the efficiency of cutting, the force on the tool in the direction of cutting, the power consumption and the surface texture. It is one of the primary factors in the life of the tool.

The obliquity of the cutting edge, defined as its inclination to a normal to the direction of approach of the metal, controls the direction of chip flow over the rake face. It has practically no effect on power consumption or on surface texture. It is one of the secondary factors in tool life.

The primary rake and the obliquity are the basic angles and they completely specify the important

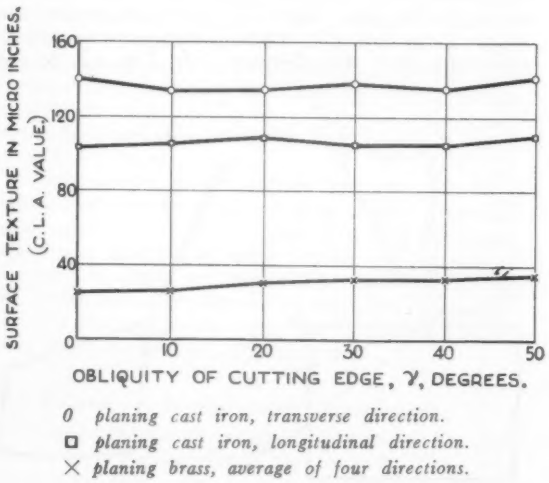


Fig. 15. Effect of obliquity on surface texture.

cutting action conditions, but further information is sometimes required to orient the cutting edge with the work piece.

Clearance

The clearance angle is required to minimise friction after cutting has been completed. It is much less important than rake. It should be measured in the relative direction of motion between tool and work and normal to the plane of recession of the work which is the same as the plane of approach. The true clearance is measured in the same plane as the so called 'true' rake. The clearance angle is in a different plane to the primary rake if there is any obliquity. There can be no justification for measuring clearance in any other manner but some of the instruments on the market measure it in other ways. The clearance of the two cutting edges of the model single point tool are shown in Fig. 17.

The main effect of clearance angle is on the life of the tool and on its conductance of heat. The cutting action quickly wears a small flat on the clearance face in the plane of relative motion and this has its effect on the dimensions of the work. The length of this flat per thousandth of an inch tool wear measured normal to the cutting edge, and neglecting the minor effect of rake, is shown in Fig. 18. The rapid rise of the curve at small angles should be noted.

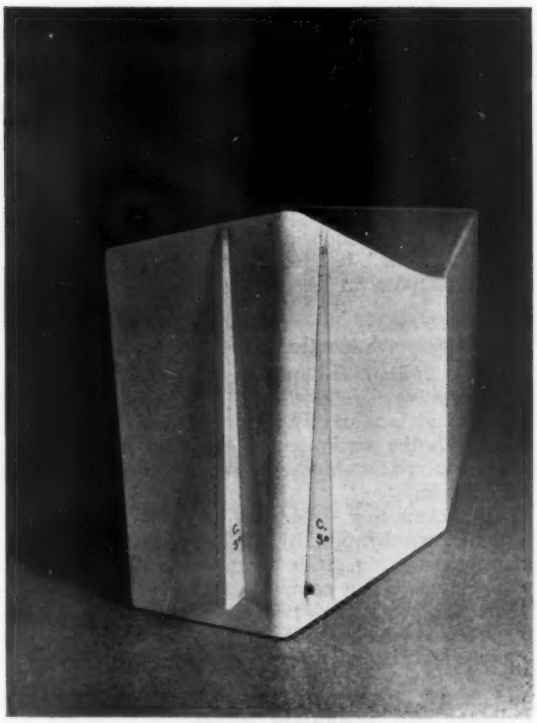


Fig. 17. Clearance of primary and secondary edges of single point tool.

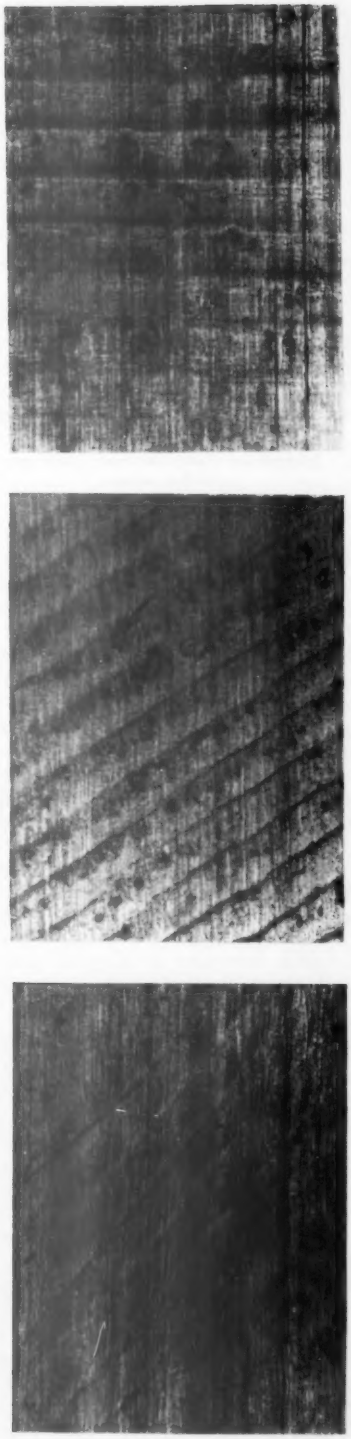


Fig. 16. Effect of obliquity on surface of planed brass.

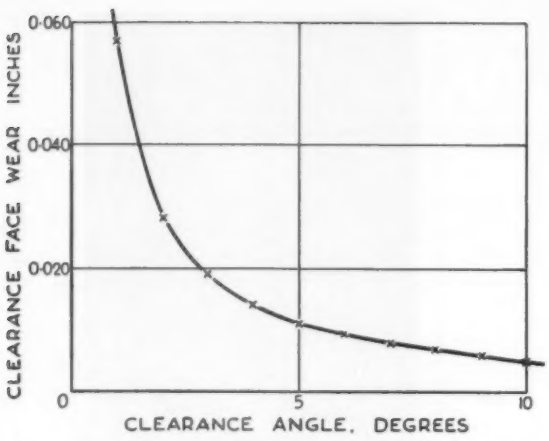


Fig. 18. Length of clearance face wear per 0.001" of radial wear.

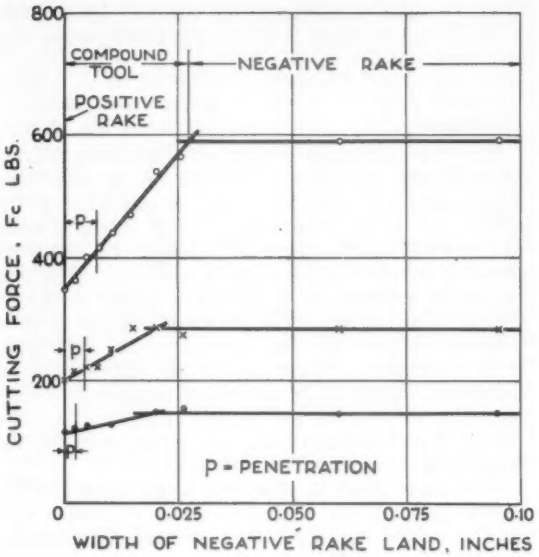
The U.S.A. has adopted the term 'relief' angle in place of clearance and there are opinions which favour its adoption in Great Britain (Ref. 9.) The two are used indiscriminately in British workshops with clearance greatly predominating, but both, unfortunately, have been allowed to enter British Standard Specifications. The Oxford English Dictionary is strongly in favour of the word 'clearance,' its definition condensing to 'space for passing' which is very apt. The nearest of the many meanings of the word 'relief' is 'deliverance from pain, distress or anxiety', a definition which is more appropriately applied to those in the workshop than to its cutting tools. The Author is strongly of the opinion that we should stick to our own good language and not follow other nations in misusing it.

Secondary Angles

(a) *Secondary rake*

A rake face may be a plain surface, a series of plane surfaces or a curved plane. In cutting it is the tangent plane at the cutting edge which is important.

A subsequent plane to the primary rake plane should be called "secondary rake". It is impossible to combine the advantages of positive and negative rake by having two planes. The main results of a piece of research on the subject (Ref. 7), are shown in Fig. 19. The power consuming cutting force component, Fc, was measured for a positive rake tool, and the tests repeated after grinding in stages a negative rake land until the tool behaved as a negative rake tool. It will be seen that there is a uniform change from one condition to the other as the primary land is varied in width. The chip has close contact with the tool for a distance about three times the penetration and after that takes no notice of any subsequent face. The practical difficulty is to obtain the best relationship between penetration or feed and the land width. It appears that the only



0 turning steel, penetration 0.0078"
× turning steel, penetration 0.0039"
● turning steel, penetration 0.0019"

Fig. 19. Effect of negative rake land on cutting force.

advantage of having a negative rake land followed by a positive secondary rake is in economy of tool material.

(b) *Secondary clearance*

To assist grinding, especially of carbide tools, and to allow for mechanical clearance in internal tools, it is common to have a subsequent clearance face at a larger angle than the primary clearance face. There is a slight justification in the meaning of the word to call this 'relief', but logic and the best use of English make the term 'secondary clearance' preferable.

Plan Approach Angle

The plan approach angle is not a basic angle at all, but it is a very practical one. It is shown in Fig. 20. Its main use is to specify the orientation of the cutting edge with the workpiece or tool and it has simple geometric relationships with depth of cut, feed and penetration.

All the existing systems of the rake specification require consideration of the plan approach angle before the cutting action conditions can be known or appreciated. The complex geometric relations between the angle and two co-ordinate rakes is the main factor which has led to so much confusion and to the obscuring of the various factors in cutting.

Primary and Secondary Edges

So far consideration has been given only to a single straight cutting edge, a condition which exists

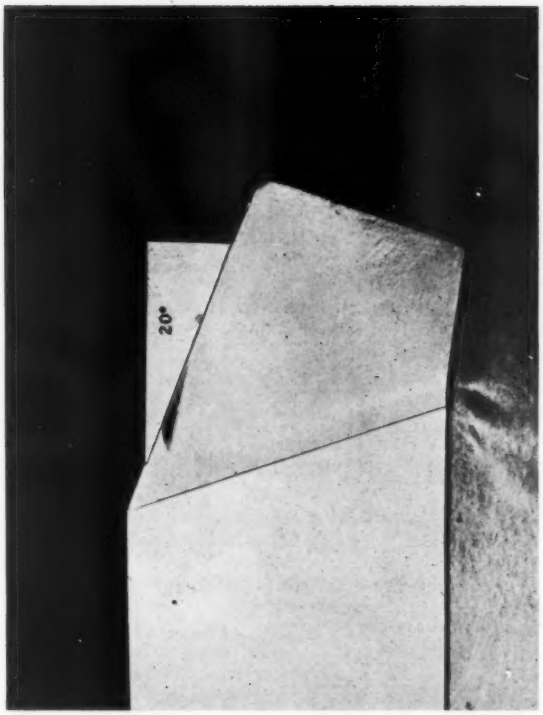


Fig. 20. Plan approach angle of single point tool.

in a few tools. The simple condition is complicated in many tools by the presence of another cutting edge and by the manner of the junction between them. In nearly all modern cutting one edge has a marked predominance so that the chip section is a trapezoid. The longer cutting edge produces the parallel side of the trapezoid and it should be referred to as the 'primary' edge. The shorter edge produces one end of the trapezoid and it should be called the 'secondary' edge. Figs. 21 and 22 show these terms applied to a single point tool and to a tap or die. A little consideration will show that it is characteristic of primary edges that they are associated with depth or length of cut, they are concerned with the bulk removal of metal and the surfaces they

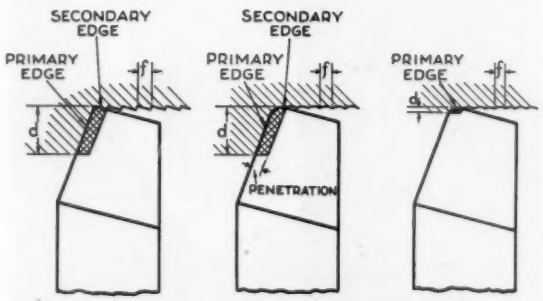


Fig. 21. Primary and secondary edges of single point tool.

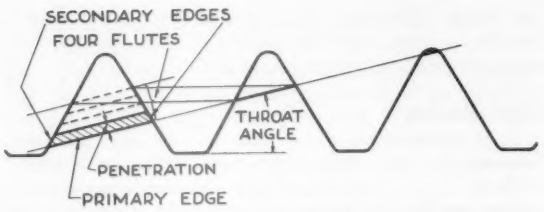


Fig. 22. Primary and secondary edges of threading tool.

generate are usually destroyed by the next cut or revolution. Similarly, secondary edges are associated with the feed motion, and the finished surface of the work is largely formed by them. Appreciation of these points alone is of great assistance in many cutting problems and justifies the adoption of the terms in specifications and their wide use.

Except for the special condition of zero obliquity and zero rake, the basic angles for the two types of edges are different and the chip flows from each edge interfere with each other. Usually the direction imposed by the obliquity of the primary edge strongly predominates, the secondary edge flow affecting one end of the chip and tending to deflect it in proportion to the relationship between the lengths of the two edges. Very occasionally the two edges produce separate chips which tend to merge into one, a good example being shown in Fig. 23. Good tool design minimises the interference by making the angle between the edges as large as possible and by modifying the sharpness of the junction angle.

A good practical illustration of the effect of secondary edges is in the chamfering of the corners of a parting off tool, so that the flow from the two secondary edges helps in reducing the chip width from the primary edge, causing the cutting to clear more readily the groove being cut.

An extreme example of poor tool design is a vee single point screw-cutting tool advanced straight into

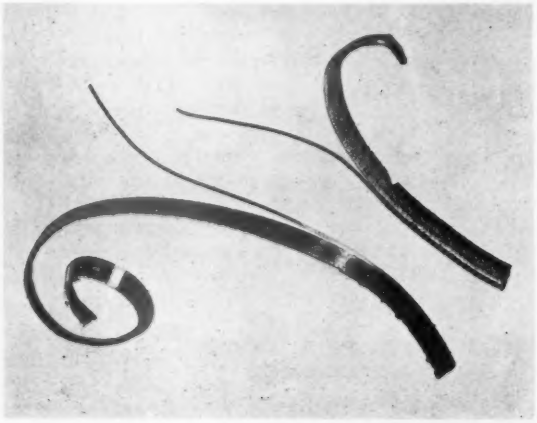


Fig. 23. Chips showing primary and secondary edge effect.

the work. Neither edge predominates, the interference is gross and the practical man has various ways of avoiding the resulting poor cutting.

Nose Radius

It is common in some tools to ease the junction between the two edges by a nose radius or a series of flats. If the radius is greater than the feed the nose radius itself is the secondary edge. In finishing cuts or in curved edge form tools the radius may become the only primary cutting edge, as shown in Fig.21.

By modifying the vulnerable pointed junction between primary and secondary edges, the nose radius has the effect of increasing the life of the meeting point. This is almost invariably done on lathe tools and only very seldom on a drill. It has been proved by a number of investigators that the radius on a drill increases its life and the common omission is another example of widespread lack of appreciation of the fundamentals of various tools.

It is possible to calculate the surface finish resulting from any combination of tool shape and feed being perfectly reproduced in the work and to express the result as a theoretical surface using three co-ordinate axes. The effect of the built-up edge in cutting is to make the theoretical finish almost unattainable. The ratio between the actual finish and the theoretical is about two for brass and three for steel, but because of the effects of such factors as the size of the built-up edge being influenced by the cutting speed its value may rise as high as ten or more. When the nose radius is markedly greater than the feed, the harmful effects of the cutting action obscure the geometrical advantage in producing a good finish.

Penetration

The undistorted chip thickness, Merchant's t_1 (Ref. 3) is of both practical and theoretical importance. It is a simple geometric function of plan approach angle and feed. A good name for it is 'penetration' and it is shown as such in Figs. 21 and 22.

Modification of Tool Angles

The true major axis of the tool-work relationship is simply 'the relative direction of motion between tool and work'. It is most convenient to label the actual angles on the tools themselves and to take into account setting modifications only when their magnitude is greater than a degree. The effect of feed is most commonly less than that amount, but it may become a few degrees in screwcutting. It is a rather confusing half-truth that placing lathe tools 'high or low' affects the rake and clearance; the real state of affairs is revealed simply by considering a radius and its tangent at the cutting point.

Models Illustrating Application

General

The basic angles and the other associated angles are most easily understood when applied to single point tools of the lathe, planer and shaper type. The basic fundamentals, however, apply to all conceivable tools, and a good understanding of them is of invaluable assistance in recognising the salient features of any cutting tool problem and in simplifying a great deal of the practical differences between a wide variety of tools. This is equally true from an educational point of view, in the workshop itself and in scientific circles.

In order to assist recognition and appreciation, the Author has had made only four large scale coloured models of the cutting portions of tools which together cover the majority of all cutting tools. Proper appreciation of these few will make it easy to extend understanding to such tools as reamers and broaches which are closely allied to the models and to any other cutting tool.

(a) *Single point tool*

The basic single point tool represents any lathe or planer tool. Its particular angles are as follows :-

Primary Rake 15°	Fig. 8.	Controls cutting force and surface finish.
Obliquity 20°	Fig. 3.	Controls chip flow.
Plan angle 20°	Fig. 20.	Affects penetration.

Its rake angles measured by the three existing systems and rounded to the nearest degree are as follows :-

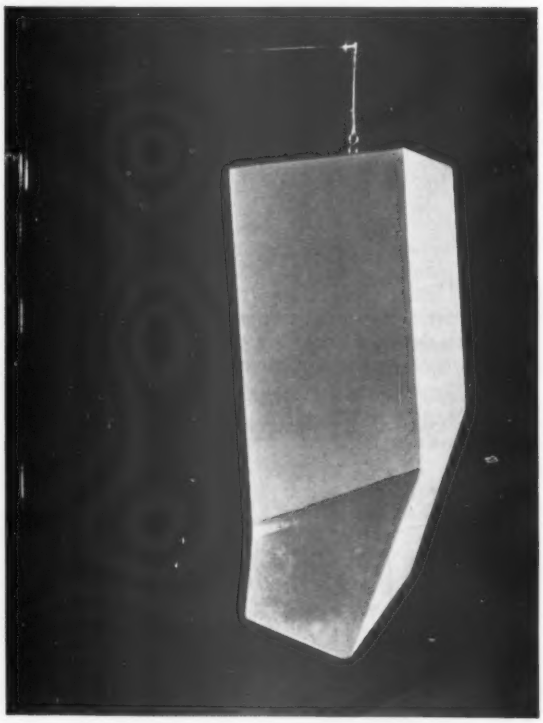


Fig. 24. One tooth of face mill.

Fig. 25. Chip flow in spiral cylindrical milling cutter.

British maximum rake 25° at 52° to cutting edge.
U.S.A. back rake 24°, U.S.A. side rake, 8°.
German back rake 20°, German side rake 16°.

This example shows that the German method comes nearest to the ideal but that all three hide the basic facts.

(b) *Face mill*

Internal lathe boring is closely analogous to face milling whether vertical or horizontal. Fig. 24 shows the single point model suspended so as to revolve round an axis and to represent one tooth of a vertical face mill. There is no real need to have different labels such as 'radial' and 'axial' rake, terms which correspond to the American side and back rake respectively. Nor is it necessary to coin new terms such as 'tooth face' (Ref. 9) when rake face and clearance face may be universally used. Even 'plan angle' becomes as perfect a term as in a lathe tool if we consider a tooth of a horizontal face cutter which is at the same level as the axis, or better still look at it from the relative direction between tool and work in any position. The primary and secondary edges of course remain the same.

(c) *Milling cutters*

The second model represents any milling cutter and in particular a cylindrical spiral mill and a staggered tooth side and face cutter.

The helix angle of the spiral mill is the obliquity and, therefore, controls the chip flow as shown in Fig. 25. The primary rake and clearance are shown in Fig. 26, and it will be seen that standard sharpening practice by grinding the clearance face is in the correct plane.

When suspended and swung the model represents a staggered tooth side and face cutter, as in Fig. 27. If used for cutting a rectangular trough the peripheral edge is the primary one concerned in the bulk removal of metal, only a tiny fraction of the surfaces it produces becoming the bottom face of the trough. In a staggered tooth there is one secondary edge on the flat face of the cutter, its primary rake and clearance being shown in Fig. 28. Only that part of it for a length equal to the penetration near the peripheral edge does any cutting, it is associated with the feed motion and produces the side of the trough.

The great geometrical similarity between it and a lathe tool is shown in Fig. 29. The main difference as regards cutting is that the milling cutter has intermittent variable penetration and the lathe tool continuous constant penetration.

(d) *Threading tools*

The third model shown in Fig. 30 is of part of a 28° helix angle right hand fluted tap for a right hand unified thread, with 2° helix angle, but it represents any threading tool such as dies. The cutting of the taper or throat angle on the thread

Fig. 26. Primary rake and clearance of milling cutter.

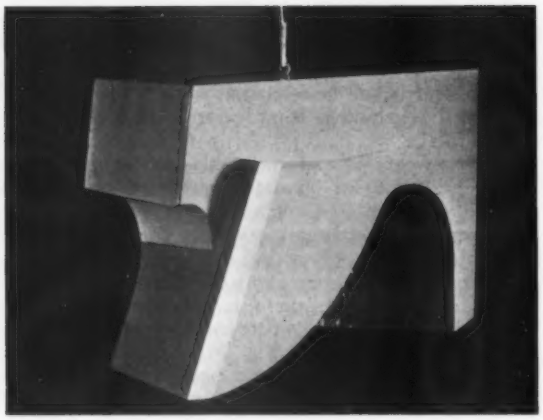


Fig. 27. Single point tool with grinding groove.

Fig. 29. Similarity between single point tool and cutter.

Fig. 31. Chip flow of right hand spiral tap.

Fig. 28. Primary rake and clearance of secondary edge of cutter.

Fig. 30. Spiral flute threading tap.

Fig. 32. Chip flow of left hand spiral tap.

profile forms the primary cutting edges, two small parts of the thread form making the secondary edges (see Fig. 22). The angle between the two helices of the thread and of the primary edge is the obliquity, the angle in the model being 30°. This controls the direction of chip flow at 30° to the cutting edge and Fig. 31 shows how such a tap tends to clear its swarf up the flutes and is, therefore, suitable for blind holes.

Cutting the flutes the opposite hand would reverse the obliquity and, therefore, the chip flow, but it is found more convenient to cut the flutes straight and to grind a left hand spiral or flat at the tapered nose. The resulting chip flow is shown in Fig. 32, where a cut away portion of the model represents the active cutting edges in such a case. Because the helices are now of opposite hand the obliquity becomes 26°. The suitability of the tap for clearing its swarf ahead of the cutting, as is desirable in through holes, is well shown.

(e) *Drills*

The fourth model, Fig. 33, is of a standard drill which represents a more complex tool, in this case with five cutting edges of three distinct types. The two main cutting edges form the two primary edges which, if correctly ground, share equally almost the whole of the metal removal. Their rake and clearance are shown in Fig. 34, but their values vary with the radius, the rake being almost zero near the centre, and the true clearance being less than the common 12° measured in the wrong plane. Their obliquity is about 5° and Fig. 35 shows the direction of chip flow.

The secondary edges are the two ends of the lands for a length equal, in a two flute drill, to half the feed. Their obliquity is the helix angle of the drill at the outer circumference, they have about minus 5° of rake and they have no clearance as the lands are ground circularly so that they are the only true guides of the drill in the hole or in the drill bush.

Fig 33. Drill point.

The fifth edge is the "chisel" edge tolerated only because it is necessary to have a binding strip of metal between the two halves of the drill. Its obliquity is zero, it being a diameter revolving round the centre of its small circle. Because of the point angle it has minus 59° rake and 31° clearance as shown in Fig. 36, and, therefore, it is an inefficient cutting edge. An additional disadvantage is that its cutting speed, already small because of small radius, approaches zero at the centre.

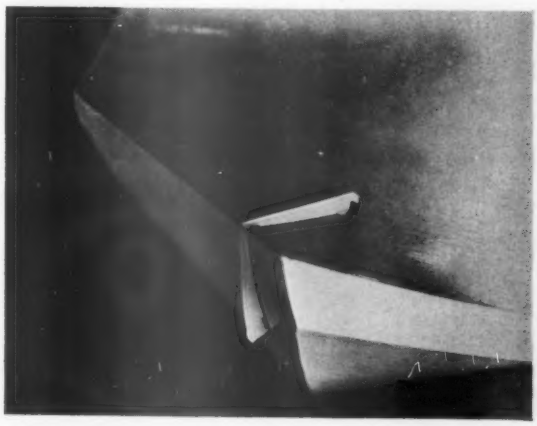


Fig. 34. Rake and clearance of primary edge of drill.

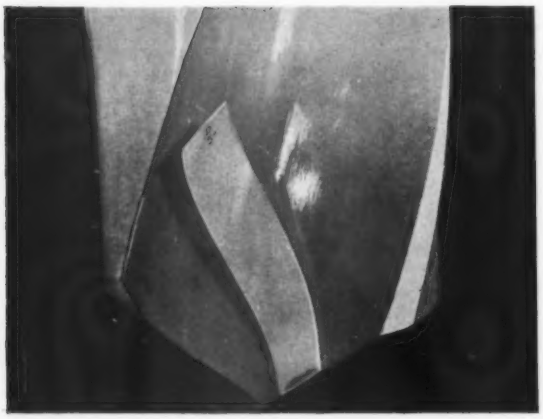


Fig. 35. Chip flow up flute of drill.

Tool Grinding

The existing systems of tool nomenclature are largely responsible for obscuring the effects of grinding the various angles. It has been shown in Ref. 9 that orthogonal methods of specifying rake in tool grinding introduce 'errors' which, to say the least, only increase the confusion.

One test of a good system of tool nomenclature is ease of tool grinding. Appreciation of the basic angles of obliquity and primary rake leads to great simplicity of off hand grinding of single point tools. This is partly because the emphasis is placed on the cutting edge rather than on the tool shank, and partly because fundamentals are always the simplest ways of doing things.

The advantages are, of course, extended to precision grinding. If a single point tool is held in a tool and cutter grinder or a surface grinder in a truly universal vice with three orthogonal protractor axes, a, b, and c, set at zero, the following is the procedure :-

(a) set the desired plan approach angle on the top vertical axis, a. This merely sets the future cutting edge in correct relationship with the tool shank.

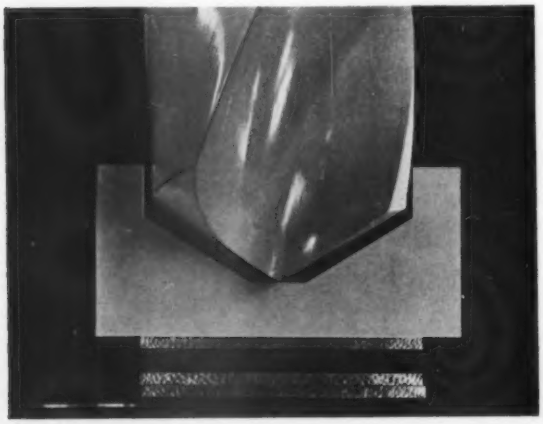


Fig. 36. Rake and clearance of chisel edge of drill.

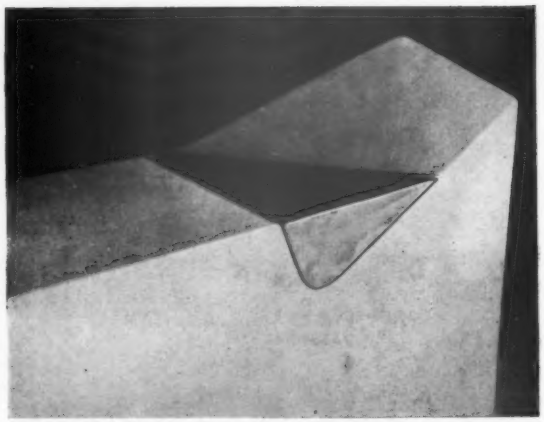


Fig. 37. Single point tool with grinding groove.

(b) set the desired obliquity on the second lower horizontal axis, b, so bringing the future cutting edge into the horizontal plane.

(c) set the desired primary rake on the third horizontal axis, c, so revolving the tool on the future cutting edge and bringing the future rake face into the horizontal plane ready for surface grinding.

No errors or compound angles are introduced. The method is easily shown by making the movements with the single point tool model, or, indeed, with any tool. It is much more simple than it appears in print. Research students of the Royal Technical College, Glasgow, rough out and precision grind their research tools with only a few minutes' instruction in the basic principles. Unfortunately, they have to be told when they go out into practice they will encounter more archaic methods.

If the tool begins as a rectangular prism it is weakened by grinding the rake face. The model, Fig. 2, shows a stronger arrangement with the rake face and cutting edges rising out of the prism. It is very common to grind the rake face so that the tool is weakened by unnecessary cutting into the prism as shown in Fig. 37. The tool can and should be ground by revolving the vice on a fourth vertical axis so that it is ground for maximum rigidity as in Fig. 2.

The principles of grinding the rake face of single point tools may be applied to any other face of the same tool or to any other tool with the same simplicity.

Proposed System of Nomenclature

A new universal system of cutting tool nomenclature is proposed which will have primary rake and obliquity as its basic angles. Such a system would be easy to understand and its use would have great practical advantages in the classroom, in the workshop and in the laboratory. From many points of view it is the only system which would stand a chance of international acceptance.

With one exception there is no need to discard the existing terms for a time, but they should be given a very definite secondary place such as an appendix in a specification. The exception is the British 'maximum rake' which is the least defensible of all terms.

Logic, simplicity, science and commonsense all call for the same names for the same things in different tools, and the terms, rake face, clearance face, clearance, primary and secondary rake and clearance, plan angle and penetration all have strong claims for general acceptance.

Problems of Acceptance

The established systems are so deeply rooted that there is a formidable problem of getting any new proposals accepted, a situation that has occurred very often in the fields of human progress. The vast task, however, should not be used as a argument against proposals that will be of great value to industry. The fact that established practice has been blind to basic principles should not be allowed to go on for ever, specially when quite a small change of viewpoint will remove the 'seals from the eyes'. The slight pain of doing so will be well rewarded by what is then revealed.

All those qualified to do so should examine and criticise the proposed terms. Confidence is felt that they will stand up to any reasonable criticism. Those who grasp their advantages should do all possible to propagate them.

Lecturers in Workshop Technology and Production Engineering in Technical Colleges will find the basic terms of great assistance in teaching the fundamentals of cutting tools, and they can do much to influence young people to adopt sound methods.

Finally, a standard specification is a powerful influence carrying much weight and authority if it is wisely drawn. In the past the British Standards Institution has given good examples of its declared policy of revision in the light of progress. Only by a profound revision of B.S. 1886—1951 can it lead the world in cutting tool nomenclature.

Acknowledgment

The Author wishes to acknowledge the assistance of a number of the staff and students of the Royal Technical College, Glasgow, and to thank the Governors and Director of that College for research facilities.

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It is hoped to include in a subsequent issue of the Journal some written discussion on Mr. Stabler's Paper. Contributions are invited, and should be addressed to the Editor at 10, Chesterfield Street, London, W.1.

THE SIGNIFICANCE OF MACHINE TOOLS IN THE AUSTRALIAN ECONOMY

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Presented to the Sydney Section of the Institution, 7th September, 1954.

WHEN I was invited to prepare a Paper on my favourite subject of machine tools, I had first thought of a purely technical approach to the matter. In view, however, of the increasing publicity given to the question of productivity in Australia, I changed my mind in favour of a general talk on machine tools in relation to productivity and the special industrial conditions existing in Australia as compared with Europe and America. My principal claim for this Paper is the novelty of its presentation by aiming at an overall treatment of the subject, without too much detail and involved statistics, yet arriving at specific conclusions from which we might be able to implement some positive action to improve the situation.

Production engineering is not an abstract science, and there are few points of issue which are not controversial in the varying circumstances which characterise our profession. I shall have more to say at a later stage about the multitudinous influences outside our own circle, which directly and indirectly affect national productivity. The question arises whether we shall content ourselves with being led in opposing directions by interests with little knowledge and experience in the art of production, or whether we can, in some way or other, take the lead ourselves and provide the necessary impetus for constructive action as professionals with the requisite expert knowledge and free from sectarian interest.

I am primarily concerned with the metal working industry, on which I can speak with some authority, and which is bearing the brunt of the criticism against high costs of production. It also has the highest employment factor of technological skill, and is now very much in the limelight over the margins issue. The skilled labour problem is coupled with machine tools for the following two main reasons:

1. we need optimum machine tool equipment to convert existing skill into commodities at the highest possible rate of efficiency;
2. we need suitable machine tools to increase the effectiveness of unskilled and semi-skilled labour, so that the higher degree of skill can be diverted to priority work which can utilise such skill to greater advantage.

This Paper first deals with the technical and economical trends of development in modern machine tools, then highlights the problems of selection, finance, utilisation, maintenance and obsolescence, finally concluding with some constructive proposals by integrating the conclusions drawn from each subheading.

Technical Trends

The most conspicuous feature of technical development is the speed at which it is proceeding in America and Europe, which is progressively increasing the gap against our own industry. With the exception of very few concerns with the turnover, finance and know-how to keep reasonably abreast, we must resolve ourselves to this increasing gap in plant engineering, unless we decide to follow our own line of development.

The machine tool industry is forming two distinct branches, one specialising in the general purpose types which can be sold from catalogues, the other concentrating on special purpose machines designed for a specific component or operation. The tendency

is for these not to mix; from balance of personnel to the paint on the finished article there are considerable differences.

For either type, the tendency is towards unit-construction, which is particularly marked on milling machines of all types—especially plano-millers. Coupled with unit-construction is the tendency for large users to build their own machines, and it is now possible to purchase machine tool unit heads from the car manufacturers such as Austin in England and Renault in France.

General purpose machines, of the type with which Australia has been essentially concerned to date, are undergoing a process of evolution which can already be clearly recognised. Apart from tool rooms where the problem is to conserve skill, the general purpose machine will continue to dominate the field of small lot production. Two schools of thought are emerging, the one which claims that machines are becoming too expensive and complicated, the other demanding operation by unskilled labour or fully automatically, regardless—within reason—of the complications built into the machine.

The hand-setting G.P. type of machine has the minimum number of components, pick-off gears instead of gear boxes, high speed range, individual motors for all movements, is built to a standard capacity chart, but is very strong and free of vibration for full utilisation of carbide tools. The machines require semi-skilled or skilled setters. Being fully standardised, they can be built to sell at a very low price.

Programming Machines

The auto-setting G.P. types are also called "programming" machines. There is a particularly strong interest in these machines in Germany. The principle is that either a master component is set-up in the machine which then records this setting either mechanically or electronically, to be repeated fully automatically, or the operations are recorded on a magnetic tape or on punched cards, not necessarily on the machine, so that the machine attendant is only concerned with tool-setting for the first component.

Automatic profiling machines and copy turning lathes are intermediate stages in the development.

All this may sound fantastic but machines have actually been built experimentally. A recent issue of "The Engineer" gave a detailed report of the experimental application of magnetic tape control to a Heald Fineborer at Alfred Herbert's Works in Coventry. The punched card method of control was mentioned by Mr. Taylor in his Paper before this Institution last year. The interim phase is the equipment of more or less conventional machines with preselective devices, to make sure that speeds and feeds are as selected by the Planning Office, and not at the choice of the operator.

Opposed to these general purpose machines are the special purpose types built as a rule for a single set-up although here, again, maximum use is made of the unit-construction principle, so that machines are not entirely scrap if no longer required for their original job. For large-scale mass production, and this applies equally well to instrument manufacture in contrast with motor car production, again two construction principles are emerging with clearly defined separate characteristics. We have the principle known by that charming American word—"automation"—originating, I believe, at the Ford Motor Co.—of combining all mechanical means of production, i.e., standard and special machine tools, clamping mechanisms, fixtures, inspection devices, conveyors, scrap removal, etc., operating within a small or large group—or a whole department for that matter, to function as one unit without the attention of even a single operative. Everything is programmed from a master control or brain, and so interlocked and foolproofed that scrap is virtually impossible. In contrast with "automation", the other development covers so-called "transfer" machines, which are virtually self-contained machines made up with unit heads, to give a sequence of up to a hundred or more individual operations on a particular component, with automatic transfer from one fixture to the next, each fixture often checking the accuracy of the previous group of operations.

New Machining Processes

Novel machining processes are consolidating themselves such as the electric spark discharge method—especially for extra hard materials such as tungsten carbide; the "hot-spot" method of preceding the cutting tool with an oxy-acetylene flame; turning with a rotary tool similar to a milling cutter; and the controlled removal of metal by electrolysis and with chemical solvents.

In machine construction, hardened steel replaceable ways and plastic slide-facings are superseding cast iron. Journal-type bearings are coming back into popularity at the expense of ball and roller bearings, to ensure absolute freedom from vibration.

Machines are being virtually designed upside down to assist in the flow and removal of swarf. Automatic gauging is gaining ground, either in the form of separate inspection machines or with such gauging devices actually incorporated in the machine tool. Air gauges of the Solex type are gaining in popularity because of their robustness and absence of gauge wear.

Hydraulic mechanisms still hold a lead over combined mechanical and electronic actuation, but both systems are under strong development pressure to overcome inherent weaknesses in operation and maintenance.

In the face of this bewildering scene of activity in the machine tool field, I am relieved to see no sign yet of incorporating nuclear physics, though Professor Messel may have different ideas on the subject.

In the cutting tool field, mechanically-held carbide tool tips are superseding brazed tips.

What is our reaction to these overseas developments? The N.S.W. University of Technology will provide a nucleus of research on advanced lines so that we have at least a small body of experts available, especially under emergency conditions. Major developments at this stage will be slow, since the

number of scientific workers required increases almost with the square of development projects to be undertaken.

These men are simply not available. Because of difficulties in maintenance and utilisation, we should steer clear of more advanced overseas designs. Where their installation is justified they should be purchased on merit, irrespective of origin. I think the time has come, however, when Australia should get down to developing a nucleus of a planned machine tool industry. It is necessary for strategic reasons, both in respect of defence and national productivity, and it would set a standard for skill and precision work which we badly need. For our small lot production, and to get rid of that large percentage of obsolete plant in small and medium-size concerns in particular, we want cheap and simple general purpose machines in appreciable quantities, built to a standard pattern of types and capacities for all basic operations. The inadequate efforts made so far by Australian machine tool makers have largely followed the tendency of copying obsolete overseas models.

Economic Trends in the Industry

There is one important feature when comparing ourselves with overseas. Machine tools, there, are a primary concern of Government; here we have apathy and an overriding interest in petty party squabbles, the right to buy a drink or petrol when we feel like it, and so on. But open any newspaper and we find it repeated again and again that our costs of production are too high, our standard of living is in jeopardy, our overseas balances are dwindling. One side, for example, tells us we want more tariffs and import restrictions, the other side tells us we want them removed. It strikes me that individually they all are right, and equally all wrong. And we production engineers are supposed to solve this muddle, since most of these troubles are related to efficiency in the factory, and that is our particular concern.

Take for example the book on greater production by Mr. Walter Scott, the well-known management consultant, published in 1950. It has 685 pages of small print on our industrial relations problem alone and one is left with the impression that the situation with which we are faced has evolved over the years through jealous insistence on the *laissez faire* principle, and by virtue of its nature will never be solved without third party interference. The purely Australian point of view is inclined to overlook the fact that an abundance of natural wealth has camouflaged the mistakes made in the past, and that our achievement to date is little more than the minimum which could be expected.

Where do we stand with our production problems and machine tools in particular? Apart from essentially managerial problems with which I have yet to deal, I submit to you that we must have a national machine tool policy of equal priority, to say the least, as atomic research and any other defence requirement. Before we can implement any policy of incentive labour control or serious reduction of costs, we have to put our house in order and so improve our methods that we can apply a national yardstick of efficiency to all producers, large and small. And the place to start is with our machine and tooling equipment.

But what do our politicians know about machine tools? What are the unions doing other than fighting for an increasing share of the national output? In Britain the British Productivity Council has come to stay, as successor to the Anglo-American Council on Productivity, and I can assure you from my own personal knowledge how it was possible to change trade union policy in the few years since the last War to such an extent that there is now not only a considerable measure of sensible co-operation with management, but unions are in effect taking direct action in safeguarding the efficiency with which the human effort is being translated into results.

So I am proposing that we have an Australian Productivity Council, set into motion by the professional bodies directly concerned, supported by the Press to exercise the required political pressure, with representatives from all interests concerned—essentially Government, employers and trades unions, under the chairmanship possibly of a time and motion expert, to see that everybody is kept on the move! To arrive at a reasonably well defined plan of action, I would confine the experiment to the metal working industry, which has the highest degree of skilled labour.

Here are a few highlights which should have a topical bearing on this subject.

In this country, the highest margins are coupled with the oldest machines.

In the U.S.A., The Society of Tool Engineers has recently given a figure of 28% for the degree of obsolescence still existing there after the expenditure of thousands of millions of pounds.

Machine tool prices in the U.S.A. are only 78% higher than in 1939 despite a wage increase of 157%.

Machine tools owned by the Defence Department alone in the United States are valued at $\$6{,}000 \times 10^6$. Converted to Australian currency, and a population ratio of 20 : 1, we should be spending for defence machinery alone $£A130 \times 10^6$. The *total* value of plant in the Australian metal working industry for 1949/50, according to the 1953 Statistical Year Book, is approximately $£A78 \times 10^6$.

Owing to the increasing speed with which armaments are being superseded, there is a growing tendency in the U.S.A. to give machine tools a higher priority than, for example, aeroplanes, on the principle of "stockpiling production capacity rather than end products". (Vance Committee—1953.)

Since we shall either have a war before we are much older, or we shall be spending a large slice of the national income on security for years to come (50 years has been mentioned), defence and productivity are integrated and all expenditure should be of joint benefit to both the Services and Australian industry.

Selection of Machine Tool Equipment

I would like to introduce this heading with a slogan which I heard some time ago—"that only a

rich man can afford to buy a cheap suit". A machine cheap in price must also be cheap in value. It may be adequate for its purpose, in which case it would be justified. The point I am making is that machine tool purchase should be preceded by a careful diagnosis of requirements against the merits of the machines on offer. Strong personal and other motives are inclined to be brought into the bargain, as in the following example which happened to a friend in the trade. He was following up a quotation and the prospective customer told him he had received seventeen others and had no clue as to which was the best machine to choose. When my acquaintance asked how he proposed to go about making a final selection, his answer was that he would probably give the order to his best pal among the lot!

Crowding the Market

A difficulty which is often overlooked relative to the machine tool business in Australia, is the fact that virtually the entire world production of machine tools in terms of "makes" is trying to squeeze into this market, nominally handled by a relatively small number of distributing agents. These agents and, to a greater extent, even their sales personnel cannot, with the best will in the world, know all the technical answers for all the machines they are trying to sell. When it comes to service, the position is worse. The user in this country is, therefore, supposed to provide the "know-how" of choosing the best machine for his job and how to make it work after installation.

If it is considered that out of a total number of factories in the Australian metal working industry of just over 12,000, approximately 92% — or around 11,000 of these factories — are employing 50 people or less, we must assume that the majority of decisions on machine tool selection and purchase are made by working proprietors, and not by professionally trained production engineers. I have the greatest admiration for these small engineering proprietors, because I well know the difficulties they are faced with. I also know one thing for certain, and it is this: none of these men has the time or peace of mind to carry through a consistent study of overseas technical literature so as to keep abreast of the increasing pace of development, even assuming they have had a fundamental training in production engineering. So they buy the next best thing, possibly from a friend in the trade whom they treat with less suspicion than the unknown quantity.

At the other end of the scale I have had first-hand experience with General Motors — Holdens, who vastly prefer to buy their specialised equipment, involving highly technical discussions, through their overseas branches in America, England and Germany, and not to depend on local agents for service with very few notable exceptions.

This may sound like a condemnation of the machine tool trade in Australia, but I would emphasise again that the trade has my sympathy because of the overwhelming difficulty of dealing with an enormous variety of makes against a specifically small turnover, and physically spread over a very large area.

It still, however, leaves the small potential customer suspended in mid-air and a characteristic of 92% of the total industry deserves our most earnest sympathy and practical assistance on this vital problem of machine selection. We are faced here with as much difficulty as in trying to gain the confidence of the unions on the labour problem. We may, in the interest of the purchaser, have to oppose the trader; we may fail in our judgement as to the most suitable type of machine for a particular purpose, and we may, nevertheless, be unable to overcome individual prejudice against the impartiality of our wisdom and experience.

The only practical solution which I could put forward at this stage is that the Institution or the University, or both jointly, establish a National Library of machine tool and allied equipment, where information is available on every known maker and his programme, suitably coded and graded by capacity, performance and characteristics, with current prices. Local agents, if any, could be supplied with instruction books to be able to assess details of design and operation, and all should be made readily available to *bona fide* machine tool users. As far as the machine tool makers are concerned, I know that they would be only too happy to co-operate.

Finance

Where is the money to come from for these seemingly grandiose schemes of re-equipping our factories, extending our plant, increasing our defence commitments and last, but not least, consolidating and adding to our standards of existence? I am an engineer and not a financial wizard—so all I can do is to put forward some of my thoughts in the hope that they may at least stimulate discussion.

I have little respect for money in terms of national finance, when trying to understand how public money is handled and viewing it through the eyes of a practical engineer. It is my opinion that the small manufacturer who has to pay his wages on the dot every Friday, regardless of whether he has the cash or not, has far greater headaches than the men at the top who disperse millions and are backed by a tax-paying public who never go on strike.

Fundamentally, the manufacturer should only have one problem — that of capital erosion — over which he has no control. I refer in this connection to the Paper read by Mr. Harrowell before the Institution earlier this Session. From an accounting point of view, wear and tear allowances are a trading expense, free of tax, and granted in full by the authorities, and whether this is by way of initial depreciation allowance, or obsolescence claim on replacement of a machine, is immaterial to the Revenue expert. I fail to see how the 40% initial depreciation demand can be of benefit other than to reduce tax payable in the early days of the life of the machine against higher *pro rata* payments in later years; to provide a means for the manipulation of excess profits and possibly to create a greater measure of confidence in buying new plant — a psychological factor strongly supported by the machine tool trade.

I must emphasise, however, that this opinion on my part of doubting the value of a high initial allowance — and which incidentally may explain Sir Arthur Fadden's refusal to increase the depreciation allowance in the last Budget — presupposes normal accounting, provision of an adequate sinking fund for the renewal of plant and, most important of all, an adequate ratio of capital to turnover in the business.

The Problem of Capitalisation

The picture is radically different when we assume that the business is under-capitalised — and I am afraid that this applies to the vast majority of small establishments, especially if they were started from scratch and worked up through sheer personal effort on the part of the proprietor. Their preponderance in Australia is ample proof of the skill, tenacity and optimism of the individual Australian, and anything which I can recommend to assist him in his struggle would, if implemented, give me a particular measure of satisfaction. It is no use the accountants condemning a business with insufficient capital, as they are prone to do. When a man sees his opportunity to start up on his own, he should be encouraged to do so, provided he can make a contribution to the national economy through his personal exertion and daring. What capital he has is largely swallowed up by his initial plant investment, and these machines were probably bought with an eye to price rather than merit. For any additional equipment our friend is now dependent on his current earnings, which are already heavily taxed and burdened with his own living expenses. Yet this man must, somehow, be encouraged to buy or instal such plant which will operate at optimum efficiency relative to what he is doing; otherwise, economically he has no justification of existence. Whatever the depreciation allowance, the money to pay for the machine has got to be found first!

Frequent recourse is made to hire-purchase, and I understand the Commonwealth Bank may advance a substantial amount of the capital outlay at 6%. This method is satisfactory if our manufacturer can keep his plant fully occupied at the originally-estimated rate of earning, otherwise he may not be able to keep up his instalments. The Bank will not like this and, though fairly lenient, may have to foreclose on the deal. Rates of interest with hire-purchase companies are higher, the terms more stringent, and these should be ignored under present conditions as a solution for extensive plant modernisation.

I suppose if I suggest that the Government should subsidise the acquisition of plant of joint significance for defence and the lowering of production costs, I shall be laughed at. Against this, may I submit that every Australian today, including the primary producer, is already receiving a very considerable subsidy in the form of a living standard as high as anywhere in the world, but certainly not based on personal exertion and productivity, especially in the secondary industry, which latter, however, is by far the larger in numbers. If I am wrong, then why are we worrying about production costs, tariffs, import restrictions and the like ?

Frankly, I would not increase the depreciation rate since a low starting rate makes for good cost accounting on invested plant capital. But I would like to see a list of machine tool priorities with obsolescence factors to be revised in the light of technological development. I would like to see instructions issued to the Commonwealth Bank to accept hire-purchase accounts with a nominal deposit of, say, 10% only on all new machine tools purchased within the priority category, at a minimum interest of, say, 5%, and with special clauses against foreclosure provided the plant is in good hands, is being used in the national interest and a temporary failure to pay an instalment on time is not caused through negligence or inefficiency — but in fact brought about through reasons beyond the control of the proprietor.

What we have to bear in mind is that, without up-to-date machines installed and ready to run, there can be no effective solution to the improvement of method, and through it a serious attack on the problem of production costs. At the moment, the bulk of the metal working industry just cannot afford to make a serious move through lack of investment capital. I am not worried in this connection about the few large concerns with reasonably up-to-date plant and production control facilities. Their problem is normally one of utilisation, with which I shall deal next.

N.B.—(The obsolescence factor could eliminate secondhand machines past a given age from being accepted in part payment by the trade. They could then be more readily diverted to scrap with full obsolescence claim, if any.)

Utilisation

Full utilisation of machine tool equipment is dependent on adequate and willing labour supply, sufficient work, efficient tooling, effective direction and co-ordination from the planning engineer, and the number of hours worked. Regarding the latter, it is assumed that the machine should be used to its maximum capacity whilst in operation. The problem of utilisation is virtually synonymous with productivity and it is here we encounter our greatest obstacle — the present frame of mind of hired labour. We all know that, could we only get the unions — and through them, labour, to meet management in a joint effort, our task would be relatively easy. It would go too far for me to deal with argument and counter-argument, and I refer you again to Mr. Walter Scott's book on greater production for a complete survey of the position. We Production Engineers are directly involved in the unions' claim that management has neglected "method". In many instances, I am afraid they are perfectly right, though I doubt whether the union argument is much more than just another talking point for opposing management in preference to constructive co-operation. Significant here is the absence of trouble

in the small shops. Resulting from a reduced trading margin and insufficient capital, these small shops have poor plant and facilities. Higher margins are, therefore, often paid to attract labour to them. Labour willingly puts up with these conditions for the sake of the extra money and the national economy suffers because skilled labour is inefficiently employed.

Finding the Solution

With labour in its present frame of mind, and with management too well off to care really seriously, I can see no practical solution in sight. We pat ourselves on the back and admire our wonderful progress, about which we hear and read in print, and in speeches over the radio. When we look at the facts, and compare these with the persistent demands for more protection, which has been amply proved must still further increase costs, to be passed on to the long-suffering customer, I can't help feeling that we are living in a fool's paradise. There is something fundamentally wrong, and I doubt whether there is a single member of this audience who has the long term welfare of this country at heart, who will deny it. And again I ask, what are we doing about it to get to the root of the trouble? We Production Engineers are too much inclined to shrug our shoulders and say that it is a matter for the politicians and accountants. If there is a solution, other than War Emergency, it will be a practical and common-sense solution, and I contend, it is as much our problem as anybody's because we are trained to be practical, and to think objectively.

The Australian economy is in a unique position not comparable with any overseas country, and no outside agency is going to help us solve our particular headaches of plant — and with it labour utilisation — unless the enemy appears again on the doorstep.

Nobody wants longer working hours per shift, but to restrict the capital investment in machines to a mere 40 hours per week of 168 hours is throwing money, and with it production, down the drain. If we work two shifts of 40 hours per week, we may not have sufficient labour at present. But we could reduce our total number of machines, throw out the old ones, and afford to buy the latest equipment available. If we could kill the old idea of one man per machine, provided there is no physical discomfort, we would reduce our total labour requirement. Does anybody really believe this would lead to unemployment, other than of those who are too lazy to work — and I guarantee this would not be many ? The Australian worker, when we can get at him individually, is as good as any in the world, and better than most. The fault, in my opinion, lies as much with management as with the unions, and this has been frequently commented upon by outside observers. Until there is considerably more enlightenment all round, there is little sense in discussing joint consultation in the factories, incentive schemes and the many aids to more efficient plant utilisation with which we are familiar overseas. The change has to take place at top level and I mention again my suggestion for an Australian Productivity Council on the lines of the British Council. A fundamental change of outlook could be achieved within about five years at the outside, judging by the British example. There it was initiated out of the emergency of having to give the population food and the factories raw materials, whilst furthering another rearmament effort. Our trouble here is that the average individual is not inclined to take anything seriously, and no one with any sense would wish for an Emergency to break down some of the apathy which we have to face. I would like to see the day when the unions would apply the strongest possible interest in the utilisation of the machines, on which their members are supposed to work, and would, if necessary, withdraw labour from obsolete plant, if faced with an obstinate management.

Maintenance

I would like to say a few words about the maintenance problem.

From the moment a machine is set to work, it starts to deteriorate, and the policy of good maintenance is to see that this deterioration is kept under control. It should not be confused with obsolescence. If it is claimed that a machine is obsolescent because it wore out, then maintenance was at fault. No machine should ever wear out, but the cost of maintenance will increase with the life of the machine. Obsolescence only enters the picture when the cost of maintenance exceeds a certain value.

Strict maintenance control will only be found in some of the larger organisations, usually when a strong safety factor is involved, notably the railways and the chemical industry. The modern science of statistical quality control has also contributed to an improvement of machine maintenance. From this we can deduce the two main principles :-

1. we have maintenance based on service life which can be a period of time, or miles on the road in the case of vehicles, or any other unit chosen to divide the working life of the equipment into periods of equal performance; or
2. we apply quality control to the particular plant item and keep a Range Chart which would indicate very promptly when components or performance falls outside the control limit. Investigation may then lead to a fault in the plant, which can be rectified.

Either method has its particular usefulness. The first would be applicable to equipment which is not subject to flow production. This would cover tool-room machines and plant engaged on small lot production. The second method presupposes a frequency characteristic, or actual flow, such as in a chemical process. Any machine tool on batch or mass production could be dealt with using the Range Chart.

Maintenance at its worst is found in the small shop and, resulting from the abundance of small shops in Australia, it is a very serious problem, especially when co-related with the need for extensive machine replacement arising from obsolescence. As

with all our other problems, it is largely a matter of mental approach. Normally, the owner just could not be bothered. He wants to see the machines working, if they stop he is losing money. He is likely to be far more concerned that his motor car is regularly and carefully serviced. What helps is that the bulk of the work done in small shops in Australia is of low accuracy, and this camouflages the extent of machine neglect.

When I came to Australia one of my first impressions was the appearance of less superficial wear and tear on machines as compared with England. Then I remembered that we had a similar characteristic in England with the more ancient machines being, relatively speaking, in a better condition. The reasons may be complex and, I believe, coupled with the tendency for modern machines to suffer more severely under abuse, with a greater specific wear tendency resulting from increased work capacity and higher speeds. Comparatively more unskilled labour is used on modern machines and work through-put has been intensified — anyway as far as England is concerned. Though we have machines at home which are as ancient as any here, they are disappearing rapidly, whereas in Australia, the old types persist and this may explain the phenomenon mentioned, coupled with more spasmodic and leisurely operation. I am sure it has nothing to do with better maintenance, which would be right out of character.

A half-way step towards systematic maintenance would be to keep at least records of the money spent on repairing machines. This is a necessity for the study of obsolescence problems, and it is required for any accurate costing procedure. Human nature being what it is, the small shop will normally hide any repair cost in current job charges, so that it is passed on to the customer. I doubt whether the average small shop — and for that matter many of the large concerns — would, of their own volition, deal with maintenance as it should be dealt with, by at least fixing for each machine definite overhaul periods, irrespective of whether the machine seems to be in good condition, or otherwise, and keeping accurate cost records for each machine and plant item.

A Logical Approach

As I have been endeavouring to give, with each heading in this Paper, some suggestion for the improvement of present shortcomings, I shall attempt to do the same thing with maintenance, and my logical approach would again have to be from a national viewpoint, since so-called private enterprise appears to be inadequate. As has been shown, the improvement of our plant inventories, and plant utilisation, cannot be achieved without some form of third-party interference and assistance. Whether this be the Government or, preferably, some non-partisan organisation, I suggest that such an authority could prepare a scheme of compulsory machine insurance coupled, perhaps, with some form of protection against loss of profit through breakdowns. Privately, it has been done with electric motors. Another aspect would be, under insurance cover, a periodic inspection of the machines and the provision of expert service personnel to look after modern machines, especially in the hands of small shops without the means or justification to maintain such experts on their own payroll. The scheme could be coupled with the supply of all new machines of strategic priority on a deferred payment basis. I could think of many variations, but the essential thing is that the improvement aimed at requires the participation of a third party with an over-riding national interest.

Obsolescence

Having dealt with maintenance, we can now approach the problem of obsolescence.

Obsolescence is the extent to which an item of equipment has lost its justification of existence for the purpose for which it was originally installed. It is, therefore, relative and can vary as the result of:

technological progress;
the job changing;
change in method;
need to change the degree of skill;
breakdown or excessive maintenance charges.

Being relative, there is need for a yardstick to measure obsolescence. The Americans have, in their usual style, thought of the most virile method to approach this problem. Under their principle of "Dynamic Equipment Policy", they are assuming that the machine installed is being attacked by the machine which wants to intrude, and the existing machine has to defend its right of occupation. The new machine is called the "Challenger", the old machine the "Defender". The battle is fought on paper, with figures, and preferably with regard to a specific production job. The "Defender" has to show his record — production times, labour rates, annual maintenance costs, running cost expressed in power, tools, etc., original purchase price, rate of depreciation and capital interest, and secondhand or scrap value. The "Challenger" presents his equivalent figures, with the secondhand value of the "Defender" replaced by an estimate of the "Challenger's" value after a given number of years. With the help of a formula, the decision is made as to who wins. And if it is the "Challenger", then out goes the "Defender" with no tears shed, except that he may then attack some other machine on another job, thus becoming the "Challenger". He keeps this up until he finally breaks down and dies a natural death.

You will see the significance of this policy, since it is no longer coupled with a definite life assumption, and a machine may become obsolete within a year of its installation. Then again, it presupposes most excellent cost records and a continuous watch on the progress of machine development.

You may ask how it is possible to estimate the probable value of the "Challenger" after a given time or service life. Statistics have shown that the maintenance cost characteristic is fairly constant in relation to time and value. Such figures have been evaluated for American conditions, and would be a useful subject for research in Australia.

Accountants over here use various formulae to establish, for example, the minimum economical life for a machine when considering its installation as an item of capital investment. I prefer the dynamic policy which, though restless, is continuously working at the improvement of manufacturing facilities. It takes, however, the problem out of the hands of the accountants and depends on the production engineer with his knowledge and continuous observation of the machine tool market.

Any attempts to apply these methods to the average shop in this country would, under present conditions, be a hopeless failure. Research work at the University would be justified, and it could be coupled with the Information Library of Machine Tools and Allied Equipment which I have suggested earlier in the Paper. It could be set in motion by the Institution with or without the University participating. The move might even be started by the University — that remains to be seen, especially as to whether any action does in fact materialise.

To apply a dynamic equipment policy to the industry would primarily depend, at least partially, on a solution of the labour management problem, so that we can arrive at predictable figures of plant utilisation.

Conclusion

I have come to the end of my Paper, and it only remains now for me to survey my principal conclusions and arrive at some finality. Many of the claims and suggestions made are not novel. In 1952, Sir Douglas Copeland called for a National Committee on Productivity. In an address to the Australian Institute of Political Science, in Canberra, he outlined the difficulties which we are facing, recommending national action, and was supported by speakers such as Mr. Walter Scott. All this was published in a small book, priced at 12s. 6d., entitled "Australian Production at the Crossroads". I saw numerous copies of this book being sold off at one shilling each at Angus & Robertson's recent clearance sale and that indicates to me the extent of the public interest!

Relative to Australia, I doubt strongly whether positive action on a national scale can originate from the present set-up, because of the variety and intensity of sectarian interests. An attempt has been made by public appeal and, to date, it has failed. To wait for the healing hand of time as a result of our process of domestic evolution is, in my opinion, not good enough. External forces are at work which may catch us unawares, and if action can be initiated, it should be done as quickly as possible.

Whether you agree in principle with me, or not, let us decide on some form of action which we can set in motion here, as production engineers, in the battle against high production costs and inefficiency. The wide approach has not been successful, so let us try to start a "chain reaction" by beginning at what appears to be one of the weakest points of the structure within our sphere of interest. This brings me back to machine tools and the metal working industry.

I have mentioned under "*Technical Trends*" that a nucleus of research on advanced lines is being initiated by the University of Technology, and recommended the extension and streamlining of our Australian machine tool industry, with Government backing and guidance, and *not* influenced by the profit motive.

I have suggested under "*Economic Trends*", the formation of an Australian Productivity Council.

Under "*Selection*", I have proposed a central library of information with an advisory service, for machine tool equipment, for the benefit of especially those people to whom such information is not readily available.

Under "*Finance*", I am recommending for the purchase of all machines of priority status, an extension of the principle of deferred payment on terms readily acceptable to firms with restricted capital facilities.

I am suggesting under "*Utilisation*", that the trades unions are directly involved in achieving the maximum efficiency of each production unit.

Against "*Maintenance*" I have indicated the possibility of a scheme of machine insurance, compulsory for equipment of national priority, with service facilities by specialists not normally available to a large percentage of machine tool users.

Under "*Obsolescence*", I have put forward the possibility of using the Central Library and Information Service for the purpose of assisting in determining the relative degree of obsolescence in relation to specific production units.

Under each heading it was my aim not only to examine the present position from a critical viewpoint, but to indicate lines along which positive action could be undertaken. We might disagree as to the wisdom of the particular form of action, but this could be made the subject of discussion, which in itself would already represent a move in the right direction.

Since I am the first to appreciate that it would not be possible to set a multiplicity of such schemes into motion with immediate effect I am, therefore, winding up my Paper by proposing as the first practical step in the direction of initiating the "chain reaction", to which I have referred earlier, "that the Sydney Branch of the Institution of Production Engineers forthwith establish a Working Party to enquire into the efficiency of machine tool utilisation in the State of New South Wales; to publish all findings without disclosing sources of information; to supervise the early implementation of all recommendations agreed upon between the parties concerned, and to issue an Annual Review of the progress made in increasing *productivity*".

THE PRACTICAL USES OF ELECTRONICS IN INDUSTRY

by K. A. ZANDSTRA, A.M.I.E.E.

Presented to the North-Eastern Section of the Institution, 15th November, 1954.

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He joined the Philips Company in 1929 as a telecommunications engineer and came to the United Kingdom in 1936.

Shortly after the outbreak of the Second World War, he commenced experiments on the application of high frequency heating to industrial problems.

He was appointed to his present position in 1949.

Mr. Zandstra

ELECTRONIC engineering has made its greatest strides since the outbreak of the last War; this is understandable on account of the great demands which industry has placed upon it. Development of electronics continues at great speed and, properly used in industry, serves the purpose of improving quality, of being economical, and of creating better working conditions for the operators. In this Paper, the Author proposes to select from the vast number of available applications a few which have particular reference to the machine tool and allied industries. In most cases the descriptions given are augmented by a simplified diagram illustrating the essential principles involved.

History

Electronic engineering has as its background the study of the electron, which in our generation has transformed civilisation to such a marked degree. The electronic valve used in properly designed circuits makes it possible to perform operations with speed and accuracy which mechanical devices cannot equal. Most electronic circuits use the thermionic valve in one or other of its many forms, and the Author proposes here to give a few brief details of the types of valve generally found in electronic circuits for industrial use. The two main groups are :-

1. vacuum valves; and
2. gas-filled valves.

Vacuum Valves

Vacuum Diode

The simplest form of this type of valve is the diode. A cathode, which is heated by an electric current, emits electrons and when a certain value

Fig. 1.

of positive voltage is applied to the opposite electrode (the anode), an electric current will flow in one direction through the valve. With alternating voltages, only that part of the cycle in which the anode is positive with respect to the cathode will cause conduction. We have, therefore, a device for obtaining uni-directional current from an alternating current supply.

Vacuum Triode and Multi-grid Valves

The introduction of a grid in the space between the cathode and anode allows the electron current to be greatly influenced by applying to this grid a negative voltage with respect to the cathode; in this manner the electron current can, if necessary, be cut off entirely. Such a valve is called a triode and has found great use in electronic circuits.

Since its earliest introduction by de Forest in 1907, additional grids have been included in the construction to obtain a higher degree of amplification and control; literally millions of such valves are in use for radio and industrial purposes.

Gas-filled Valves

The Gas-filled Diode

Introduction of an inert gas into the diode described above results in a marked difference in the current conducted through the valve at any particular value of voltage, and a glow discharge is also visible. Much larger currents are permissible through a gas-filled diode by comparison with a vacuum diode of the same size. A practical application for such a valve is as a rectifier in a circuit for charging accumulators.

The Gas-filled Triode

The introduction of a control grid between the anode and cathode allows a variation in the current conducted through the valve, but with a marked difference by comparison with the vacuum triode. After the valve has started to conduct, the grid loses its control altogether and to all intents and purposes the valve behaves as a gas-filled diode. The current can then be cut off only by removing the anode voltage or by greatly reducing it. With this type of valve we have an electronic relay capable of operating at very great speed. The valve is usually referred to as a thyratron. Improved characteristics are obtained by introducing yet another grid into the valve, which is then called a tetrode.

Fig. 1 shows a number of thyratrons for industrial use.

The Ignitron

The vacuum valve and most of the gas-filled valves mentioned above have hot cathodes, which are heated by an electric current. The ignitron, however, is a gas-filled valve in which the cathode is not heated, but consists of a pool of mercury. A specially designed igniter is used to make the valve conductive and much higher currents can be handled by these valves. On some types water cooling is used to remove the heat generated inside the valve. The major use for ignitrons is in welding circuits, which will be described later.

Use of Electronics in Industrial Applications

It would be difficult to find a branch of engineering in which electronics combined with

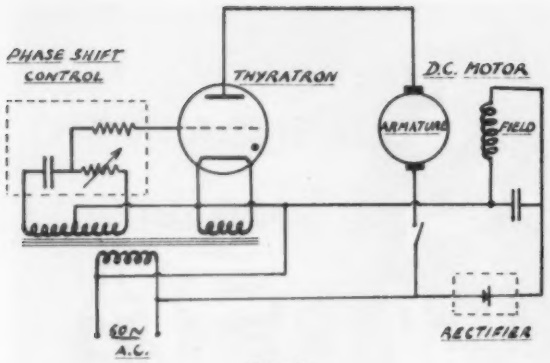


Fig. 2.

electrical engineering has not been applied. In this field the measurement of temperature, speed and light intensity, the industrial control of welding, the accurate speed control of electric motors, ultrasonics for aluminium soldering, the drilling of holes in very hard metal, the rapid heating of metals, drying and various bonding and glueing processes are but a few of the many applications where electronics are successfully used.

Thermionic valves with widely different characteristics and powers are used in a great variety of circuits for these various purposes. The Author has made a selection of some of the most interesting applications of electronics in industry covering a wide field as follows :-

1. electronic control of electric motors;
2. timing circuits and electronic switching for welding control;
3. high frequency heating;
4. electronic instruments for production control;
5. industrial television.

Electronic Control of Electric Motors

Speed Control of D.C. Motors

The speed of D.C. motors can be varied either by changing the armature voltage or by variation of the field excitation. The most common method, the conventional Ward-Leonard speed control system, depends for its operation on the armature voltage only, and a variable speed is achieved by reducing this voltage. The use of electronic circuits in a motor control system offers many advantages, for example, greater adaptability, i.e., units can be built into the actual machines, and a wide choice of characteristics.

Electronic circuits have been developed in which both armature and field voltages can be varied as additional compensation for loss of speed on load, etc. The designer has a choice of the desired characteristics he wishes to cover; for example, the following possibilities can be provided for :-

(a) increase of speed by increase of armature voltage, the torque remaining constant;
(b) decrease of speed by decrease of armature voltage, the torque remaining constant;
(c) increase of speed by decrease of excitation (field) current — the torque is reduced but the power remains constant;
(d) rapid stopping of the motor;
(e) rapid reversal of the motor;
(f) changes in motor speed according to a desired characteristic;
(g) the motor speed made independent of the load.

To satisfy some of the above characteristics a simple electronic system can be used in which, for example, speed control can be effected by varying the voltage of the armature, the field excitation being kept constant. Such a circuit is illustrated in Fig. 2; the field supply is obtained from a selenium rectifier and the variable armature voltage is obtained from a thyratron valve.

This valve has a control grid circuit in which the phase of the grid voltage is shifted with respect to the anode voltage. The armature thus obtains voltage pulses of varying magnitude depending on the setting of the control element in the grid circuit; quite a large range of speed is possible in this way.

Fig. 3 shows an experimental set-up for more accurate speed control between the limits of no-load and full-load. Here a more elaborate circuit is needed and Fig. 4 illustrates the principle involved. A 3-phase power transformer is used, the secondaries supplying power to three thyratrons which in turn supply the variable voltage for the armature. Auxiliary transformers supply voltages to :-

(a) a rectifier for field supply;

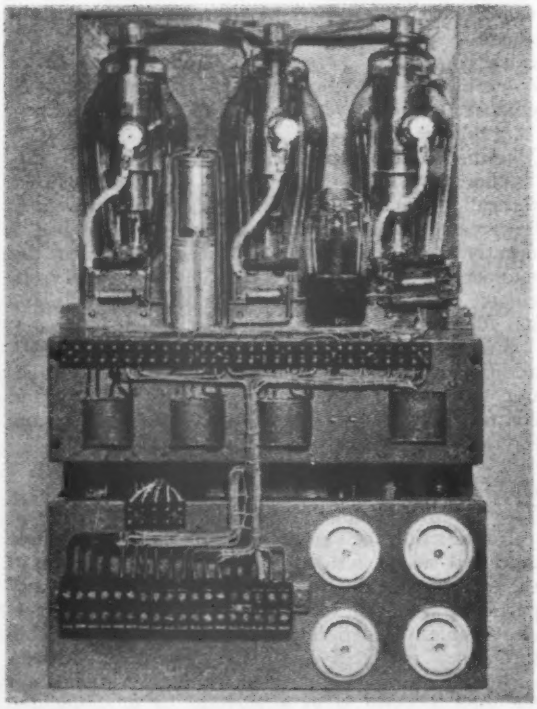


Fig. 3.

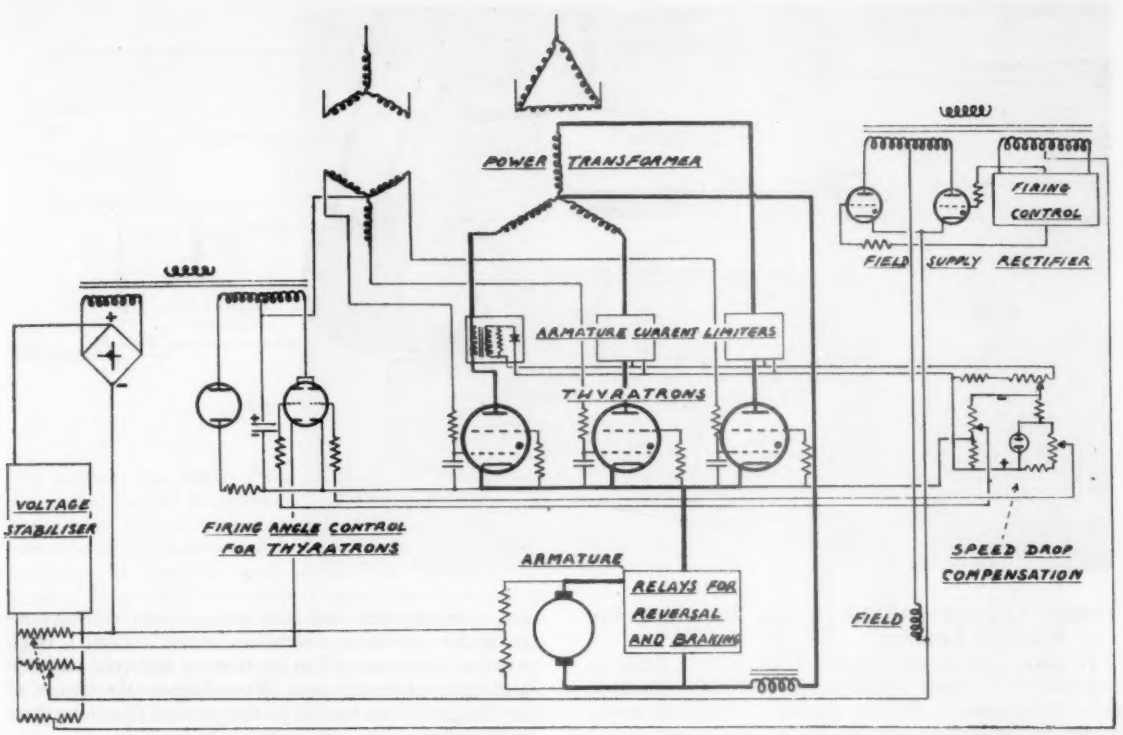


Fig. 4.

(b) two rectifiers for control of the firing angle of the thyratrons;

(c) a rectifier for obtaining stabilised voltages to be used as reference voltages.

In addition, the circuit contains relays for quick reversal and braking.

The grids of the three thyratrons are supplied with a control voltage having a phase shift with respect to the main anode voltages, and by means of the firing angle control circuit the firing angle of the thyratrons is increased or the valves completely blocked. The motor armature current is automatically limited by the introduction of current transformers in the anode circuits of the thyratrons; too high an anode (armature) current alters the firing angle of the thyratrons, the limit being set by means of a special control. This circuit gives a very wide range of speed control and stabilisation, the speed being independent of the load. The voltage drop in the armature is also compensated for and in this way it is possible to obtain a speed variation from no-load to full-load of less than 1% - 2%.

A very wide speed variation can be obtained by combining the control of the field supply with one of the controls of the regulated armature supply, a complete ration of speed control from 150 to 1 being available. Such controls can be preset and also selected by a selector switch so that any pre-determined speed can be obtained.

Fig. 5 shows a photograph of a 3-phase control device for mounting into the base of a lathe. Fig. 6 shows a production lathe with 3-phase motor control as described above, selector switch and six controls.

The advantages of electronic motor control are: greater adaptability, very low power consumption, silent and instantaneous operation, small space and the possibility of adapting the control for individual requirements.

Speed Control of A.C. Motors

For many applications, for example, in the machine tool industry, variable speed A.C. motors are used, a stepless control variation being available on A.C. commutator motors with fixed brush gear and using induction regulators for the armature supply. For very high speeds such as 20,000/120,000 revs. per minute, a high frequency A.C. supply of between 1,000 and 2,000 c/s has many advantages and, by varying the supply frequency, a wide range of speeds can be achieved.

Various circuits have been developed for supplying the variable frequency, and for low power applications high vacuum valves are often used. For higher powers, thyratrons in an inverter circuit are employed.

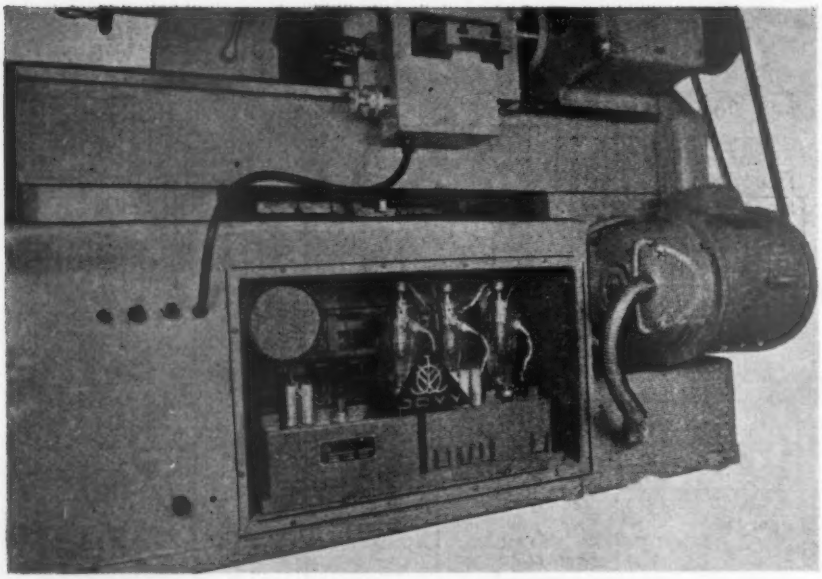


Fig. 5.

Timing Circuits and Electronic Switching for Welding Control

In almost every electronic circuit a time delay is required for certain operations or controls. Such a time delay may be for the duration of one or more cycles or for several seconds. This delay in time in electronic circuits is obtained by the discharge of a capacitor through a resistor, the decrease of voltage following a definite law.

In combination with electronic valves, numerous circuits have been developed for different purposes and characteristics and wide use is made of time control in the operation of welding control circuits. High vacuum valves as well as thyratrons and cold cathode discharge valves are used, depending on the choice of the designer with regard to the various characteristics of the valves.

A simple time control circuit, as shown in Fig. 7, is suitable for giving a variable time control for a welding current up to a few cycles. A hot cathode thyratron valve is used and a relay in the anode circuit connects the mains supply to the transformer of

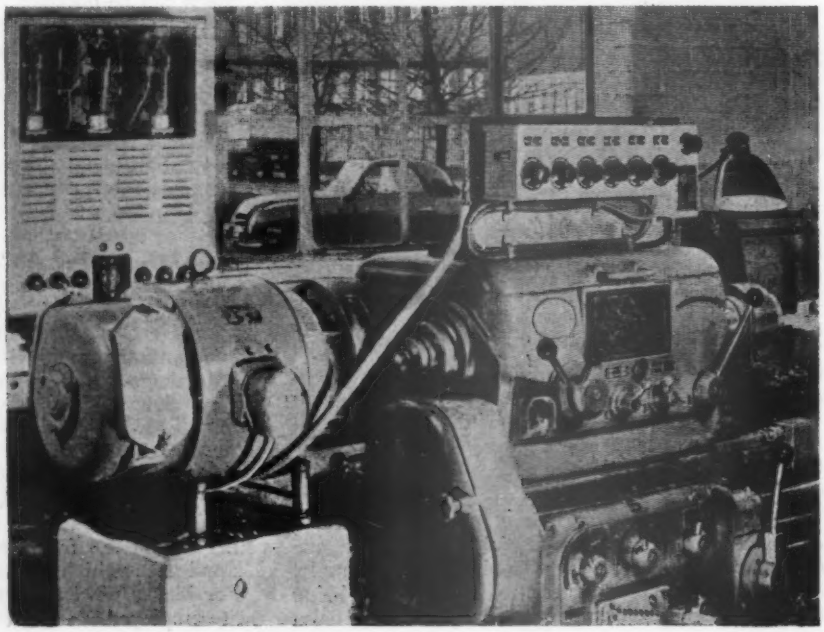


Fig. 6.

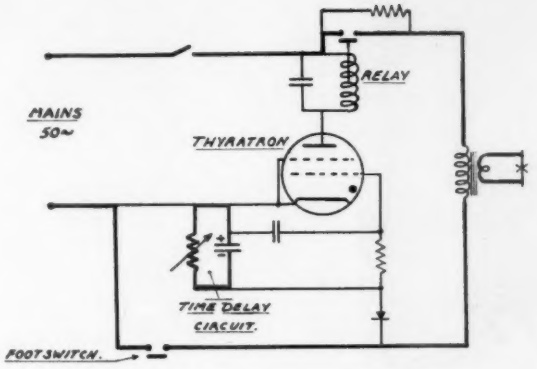


Fig. 7.

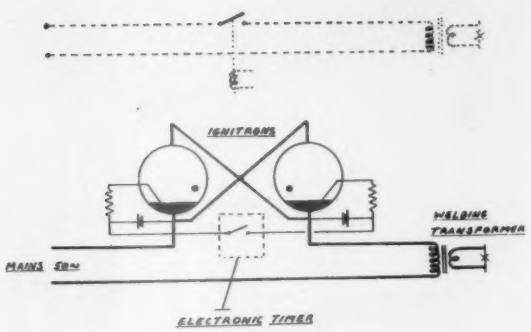


Fig. 8.

the welder; the other phase of the mains supply is connected to the transformer *via* the footswitch. A time delay circuit is connected between the grid and cathode of the valve, whilst a small selenium rectifier supplies the negative grid voltage for blocking the valve. When the footswitch is open, the thyratron is blocked by the negative voltage and the relay contact is closed. When the footswitch is closed, the welding current flows for such a time as it takes to discharge the condenser through the grid delay circuit and to drop the negative voltage of the grid to a value at which the thyratron fires again, thus energising the relay and thereby interrupting the welding current.

Numerous timing circuits are in existence with varying degrees of accuracy and range, and circuits with multiple timers are used for sequence control, for example, in resistance welding. Here, in conjunction with pressure switches, electronic timers are used in the following typical control sequence :-

1. pressure is applied to the electrodes to hold the workpiece;
2. the article is preheated by preheating current switched on at a certain time;
3. the full welding current is applied for a certain time;
4. the pressure on the electrodes is decreased during the welding cycle;
5. decrease in welding current for post-heating and increase in pressure on the electrodes (forge time);
6. the current is switched off and the weld allowed to cool under high pressure.
7. removal of the pressure and separation of the electrodes.

Several of the above operations need only fractions of a second and electro-magnetic contactors, which are used on the simpler welding equipments, would not have and could not maintain the accuracy required for such precision welding. The ignitron valve mentioned above has been developed to perform these operations, and two such valves connected as in Fig. 8 will perform the same function as an ordinary electro-magnetic contactor but with this advantage,

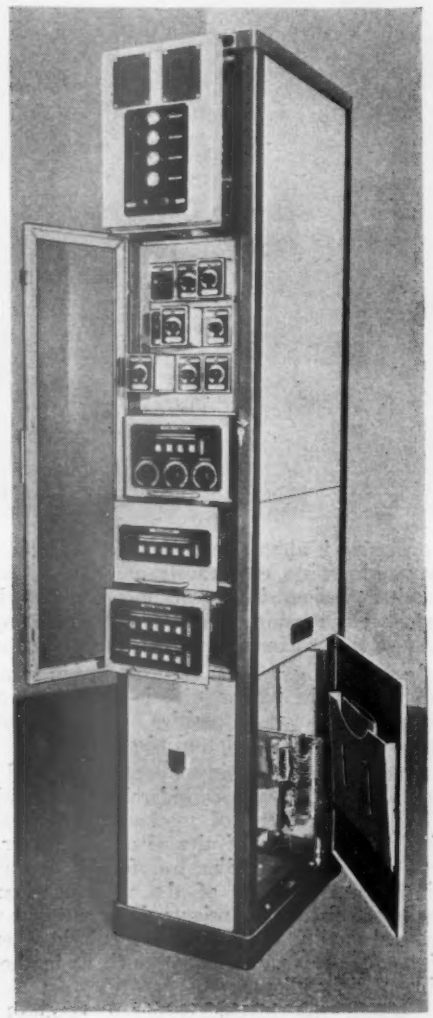


Fig. 9.

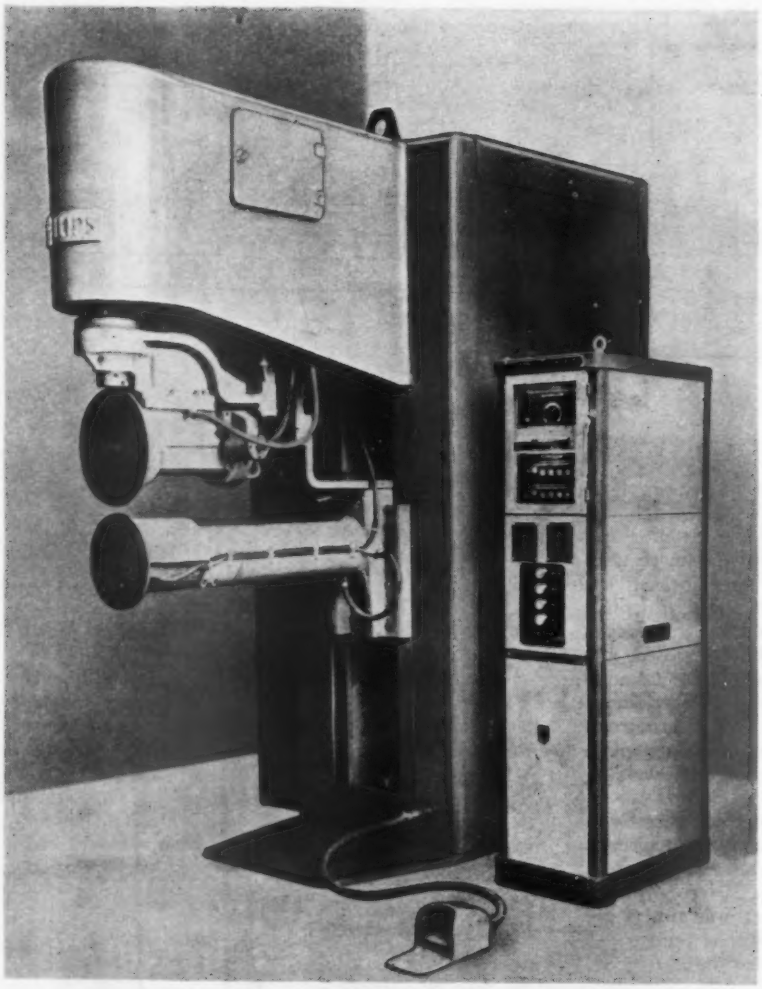


Fig. 10.

that operation is almost instantaneous and at a speed unobtainable with ordinary contactors. Ignitrons are made in various sizes and ratings and are selected in such a way that the heat dissipated during the duty cycle is not excessive.

Referring to Fig. 8, each ignitron fires in turn over one half-cycle, the igniter initiating the firing of the ignitron, whose anode is positive at that instant, the other valve being blocked, and *vice versa*.

A combination of ignitron contractors and electronic timing circuits is considerably more suitable than any arrangement of mechanical devices, but despite the accuracy of the electronic timer, the current through the welding transformer depends on the instantaneous value of the voltage when the ignitrons are fired. Transients do occur and welds of unequal quality may result, particularly when the requirements are very stringent, such as in the spot welding of light alloys.

To obtain the higher accuracy required, the ignitrons are triggered by synchronous pulses from the mains supply through two thyratron valves, in such a way that transients do not occur and in this way the greatest possible accuracy is obtained.

Fig. 9 illustrates such a complete electronic control equipment, the various panels of which are removable for quick service.

Figs. 10 and 11 show a seam welder and a spot welder, respectively, equipped with electronic control. These welders produce welds to the highest technical requirements.

High Frequency Heating

One of the first uses of high frequency heating was in the manufacture of electronic valves and during the last 20 years its applications have become increasingly popular.

High frequency heating covers the heating of metals, which is called induction heating, and the heating of non-metals such as wood and plastics, which is called dielectric heating. The Author proposes here to cover the heating of metals only because of its wider application in the machine tool industry.

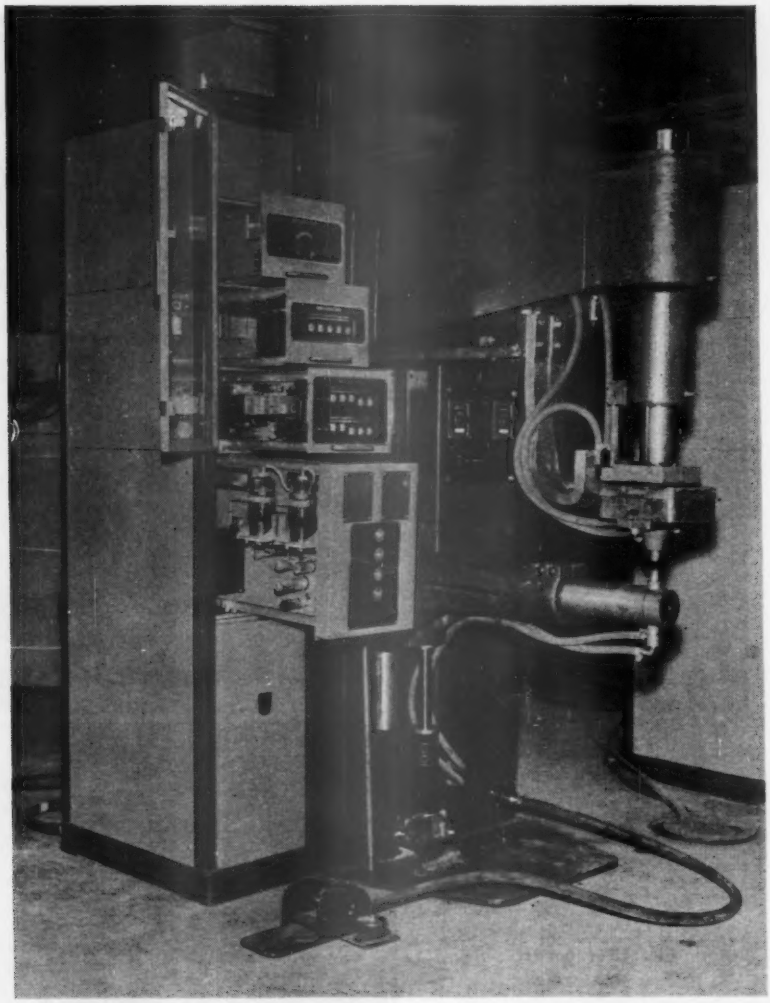


Fig. 11.

In the high frequency heating of metals, the heat is produced in the metal by means of eddy currents, which are generated in the article by the alternating magnetic field from an inductor coil carrying the high frequency current. Various frequencies are used to produce the heating, such as :-

1. 50 c/s (mains supply);
2. frequencies generated by motor alternators, generally up to 10,000 c/s;
3. spark gap oscillators up to approximately 100,000 c/s;
4. valve generators covering a wide range of frequencies, generally up to 1 Mc/s.

Valve-driven generators have an extremely wide scope and because of the use of electronic valves the following advantages are apparent :-

(a) stable electrical characteristics over long periods;
(b) high concentrations of power can be obtained much more simply than by other methods;
(c) heating can be precisely localised;
(d) a very large variety of applications are possible with these generators.

Electronic valves are obtainable with characteristics especially suited to the generation of large currents

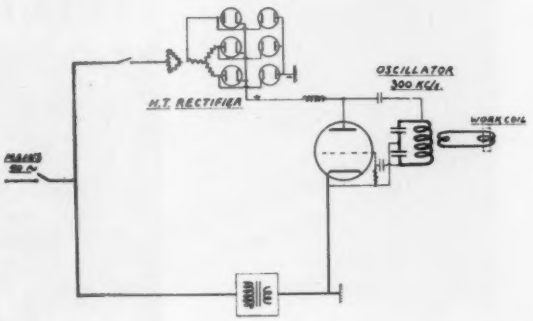


Fig. 12.

Fig. 13 (*above*).

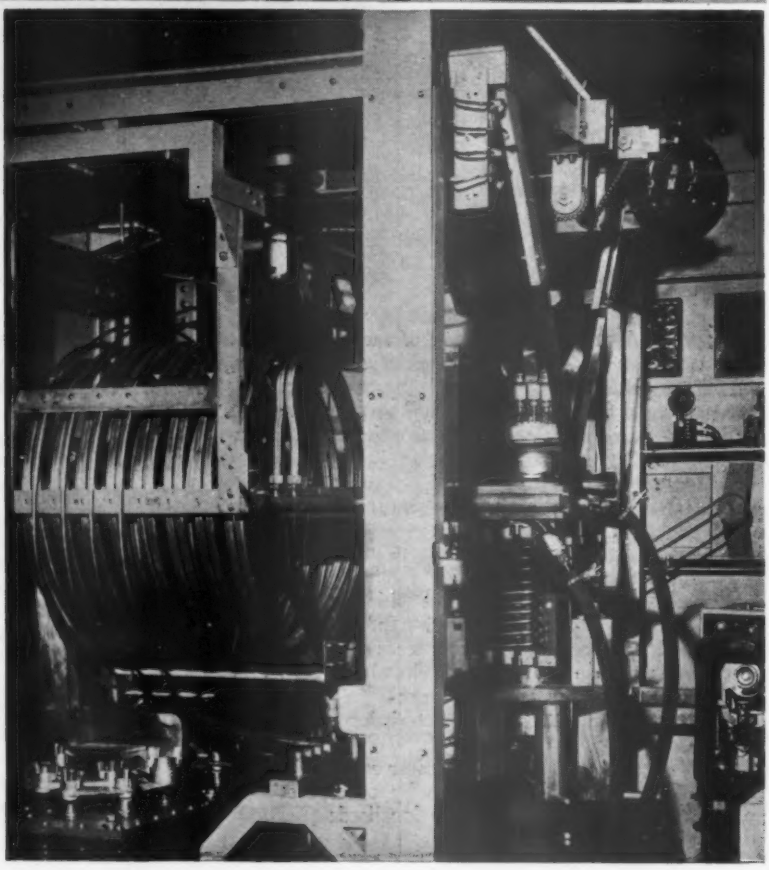


Fig. 14 (*right*).

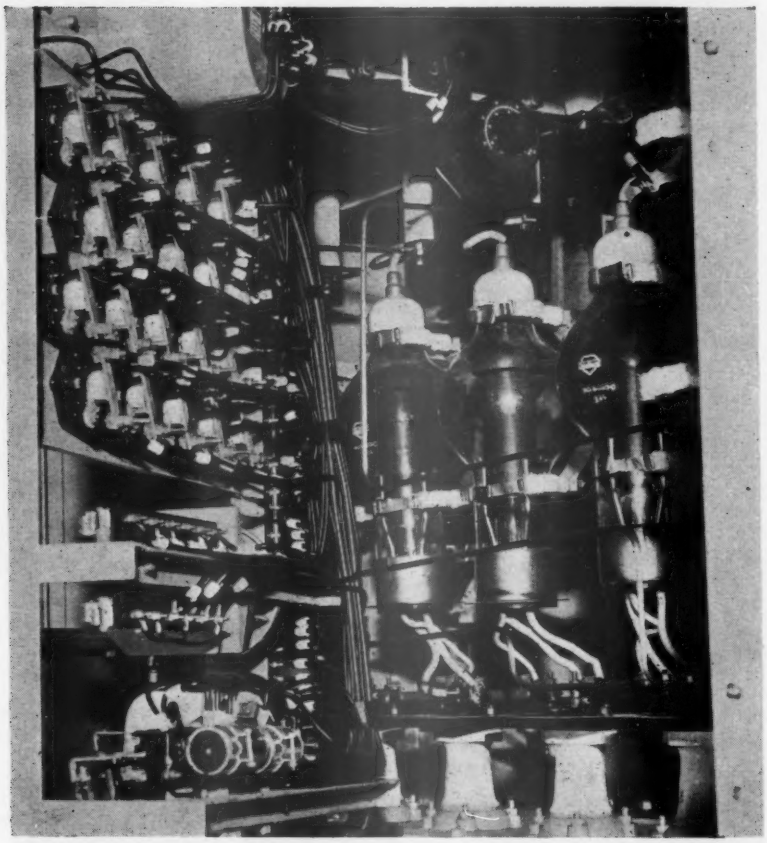


Fig. 15.

at comparatively high frequencies and output powers of up to 200 kW are realised. High vacuum valves, usually triodes, are used and the high tension supply necessary for the anodes is normally obtained from gas-filled rectifying valves.

The basic circuit of a high frequency heating generator is shown in Fig. 12. From the 50 cycle mains supply a high tension rectifier provides D.C. at the required voltage for the anode of the valve, the filament being supplied with 50 cycle current. The valve is connected to an oscillatory circuit which supplies power at a frequency determined by the circuit constants, namely capacity and inductance.

A matching device then supplies the large current to the inductor coil necessary for heating the article. Fig. 13 shows two extreme sizes of generator and Fig. 14 a close-up of the oscillator section of an H.F. generator, while Fig. 15 shows a close-up of a high tension rectifier.

Practical Applications

The high frequency currents which are induced by the inductor coil are confined to the surface layers of the metal. These currents are opposed by the electrical resistance characteristic of the various materials and heat is therefore produced on the surface of the metal, but conduction of the heat into the metal farther away from the surface takes place fairly rapidly.

By varying the magnitude of the high frequency currents, we can control the rate at which the heat is induced in the surface of the material. We can, therefore, through heat a piece of metal as is necessary for forging or hot pressing, or we can surface heat the metal as is useful for surface hardening.

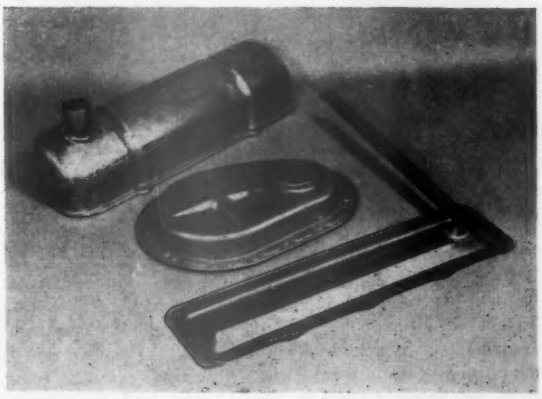


Fig. 16.

Fig. 17.

For processes such as soft and silver soldering we can also make use of the controlled rate of heating into the article, and by using specially designed inductor coils we can limit the heat to a comparatively small section of the article, which can be very useful in avoiding distortion.

The Author has selected a few applications from the vast number of induction heating processes installed in this country, as follows :-

1. silver soldering;
2. surface hardening;
3. precision casting.

Silver Soldering

Fig. 16 shows a selection of pressed steel articles in quantity production to which separate components have been silver soldered by high frequency heating. In these applications, the work was carried out on a 6 kW high frequency heating generator coupled to a dual jig, as illustrated in Fig. 17, the high frequency power being switched automatically from one position

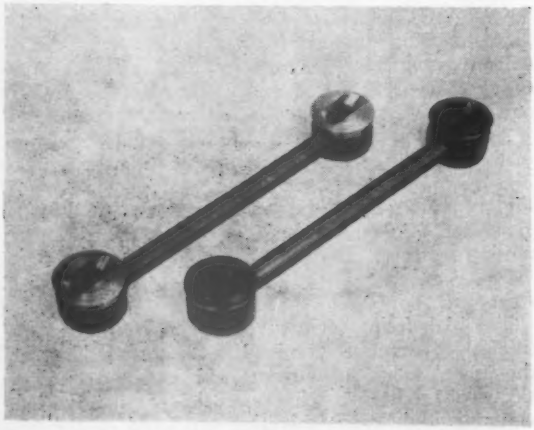


Fig. 18.

Fig. 19.

to the other for greater utilisation of the generator. A heating time of 15 seconds is sufficient to produce a perfect joint, and compared with more conventional methods, great economy is realised, the removable jigs facilitating changeover from one component to the other.

Surface Hardening

Two principal methods are generally employed, namely :-

(a) single shot treatment;
(b) progressive treatment.

(a) *Single Shot Treatment*

An example of (a) is illustrated in Fig. 18; this is a steering wheel component, the internal faces of which have been hardened. The practical set-up is illustrated in Fig. 19. showing the article in position before the quenching head is lowered. The macro-photograph (Fig. 20) shows the hardened layer, and it is obvious that against carburising treatment a great saving in time and labour is achieved. The time taken for treatment is five seconds utilising 10 kW of high frequency power and no further treatment to the hardened component is necessary, a hardness figure of 800 VPN being obtained on a 45 carbon steel.

Another example of single shot treatment is the hardening of a gear wheel, as illustrated in Fig. 21; this also shows the depth of the hardened layer after etching of the sample. It will be noticed, however, that the hardened pattern does not follow the contour of the gear, as is the case with carburising treatment. The process can be performed by induction heating, but a high power density is required to combat the heat conduction into the metal and the capital cost is thereby increased.

The majority of manufacturers of gears for gear boxes, etc., find a pattern as illustrated perfectly

Fig. 20.

satisfactory and economical, and the method adaptable to the production of a large variety of gears. Fig. 22 shows a complete gear hardening equipment in use in a motor car factory, where a 25 kW output valve driven generator is employed.

(b) *Progressive treatment*

In order to obtain relatively thin hardened layers, a high concentration of high frequency power is essential, and the article is moved at constant speed through the inductor coil whilst a quenching liquid is sprayed through slots or holes on to the heated portion. On carbon steel of suitable carbon content (.45%C), a fine structure is produced with uniform hardness and close tolerance, which leaves the core of the metal untreated.

Fig. 23 shows a splined shaft and a plain round shaft with the hardness patterns achieved after heat treatment at a speed of 3 ft. per minute and a power concentration of approximately 2 kW per square centimetre. The high power concentration referred to above is obtained by means of a high frequency transformer (concentrator) using a single turn inductor as work coil, and very high currents are thus produced in this coil.

Fig. 21.

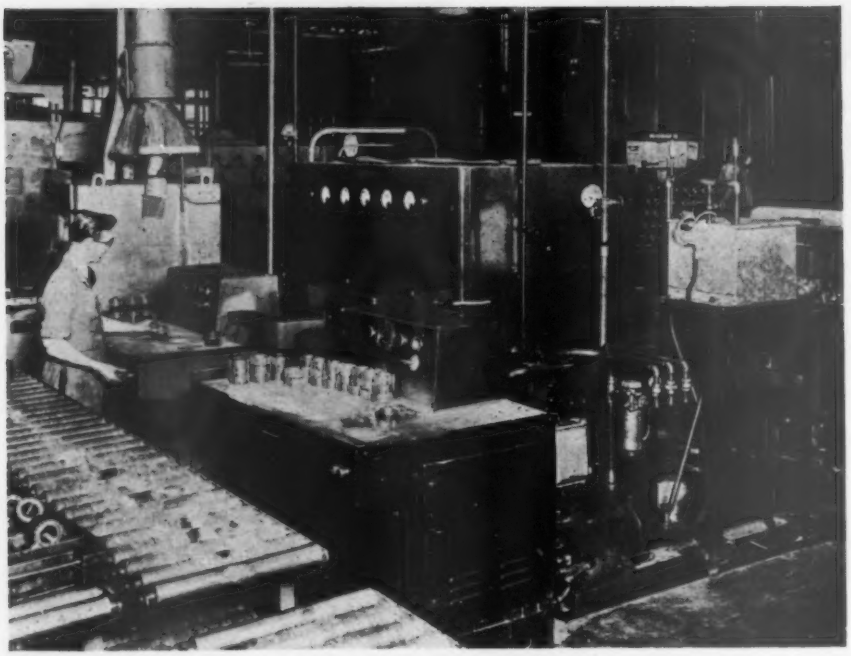


Fig. 22.

Precision Casting

For the melting of relatively small quantities of special steel for precision casting, valve-driven generators are used for quantities of metal up to 50 lb. For most applications amounts of between 10 and 20 lb. of high grade metal are treated, using a 25 kW output generator. Melting times of 1 lb. of metal per minute or better are obtained and temperatures up to 1650°C. are often used on the special nickel chrome steels.

Special moulds are made by the "lost wax" technique using special refractory material with a binding agent. After the drying process, the moulds are heated and afterwards placed on top of the melting crucible.

When the metal has reached the pouring temperature, the hot mould is clamped firmly to the melting unit and the entire assembly is quickly turned upside down, the hot metal being thereby forced into the mould. Great accuracy is obtained with precision cast articles and various metals can be used.

Melting by induction heating has the great advantage that no impurities are picked up by the metal, and usually oxidisation can be prevented by inert gas, which is admitted to the upper part of the crucible during melting. For metals where the carbon content is critical, melting by means of high frequency generators offers great advantages. Fig. 24 shows a selection of various parts made by precision casting and, against conventional production methods, a great saving in labour and time is obtained.

With precision casting it is possible to cast to fine tolerances parts which would be virtually impossible to manufacture using ordinary machining methods. As there is no limit to the type of metal which can be melted, intricately shaped milling cutters, boring tools, etc., can be made from tungsten steel using this process. After heat treatment and final grinding, these parts are used in production and, when worn, can be melted down again and then recast.

A new technique invented during the last War and which has found great favour is the shell moulding process. In this case the mould is not produced from a wax pattern but from a metal pattern, which is divided into two halves, each mounted on a flat plate. The plate is then heated to approximately 250°C. and placed face downwards on a box containing a mixture of fine sand and special resin. In this way, a shell of roughly $\frac{1}{4}''$ thickness is formed on the pattern which can be finally cured by heating. Both halves when joined together form the mould into which the molten metal is poured.

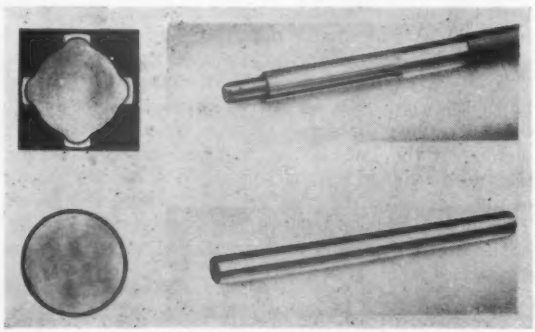


Fig. 23

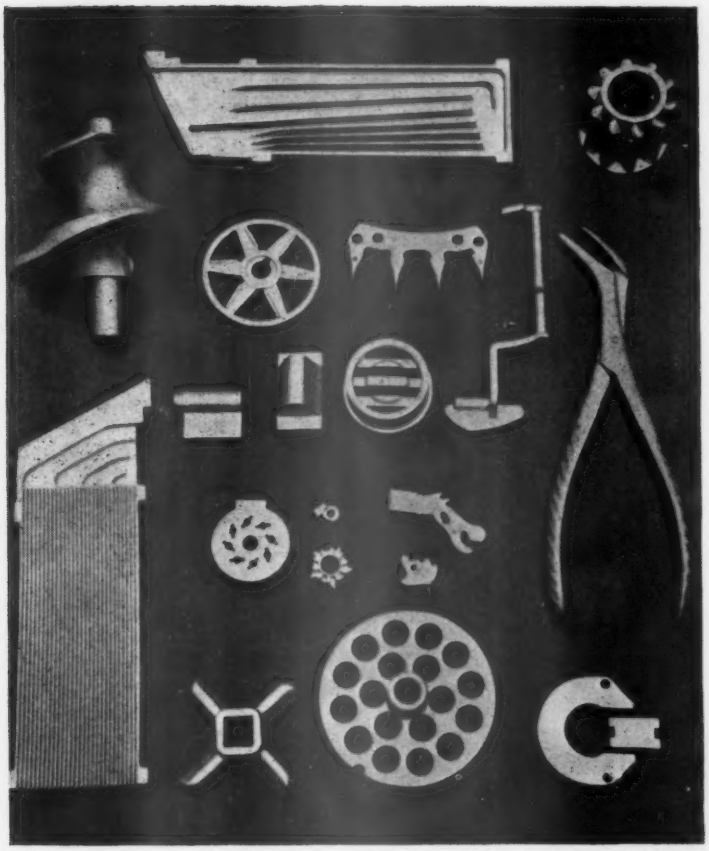


Fig. 24.

It has been found very convenient to melt the metal in an induction furnace prior to casting in the mould.

Electronic Instruments for Production Control

Many electronic instruments for highly accurate absolute measurements are at present available for use in laboratories and research departments. Not all are necessarily suitable for use in inspection departments or in conjunction with machine tools.

Two typical instruments, which have recently been developed for use in production departments, perform the following functions :-

(a) assist in accurate mechanical gauging;
(b) compare surface finish of a machined article against a standard.

Electronic Measuring Equipment in Conjunction with Mechanical Gauging

The accurate gauging apparatus is a combination of a sensitive electronic measuring bridge with special pick-up attachment and a Solex pneumatic gauge, coupled to the tool rest of the lathe.

Such a combination is shown in Fig. 25, in which the Solex gauge is mounted on the left of the measureing bridge. The right-hand scale of the Solex gauge is calibrated in tenths of a thousandth of an inch, one thousandth of an inch appearing as 10 inches on the liquid column.

On the scale of the measuring bridge a pointer deflection of four inches represents one eighth of a thousandth of an inch—a magnification of about 30,000 times, which is roughly three times the sensitivity of the mechanical system. A special pick-up is inserted in a standard gauge for measuring the internal diameter of the article in the chuck.

The measuring bridge uses a carrier wave of 4,000 cycles/sec. derived from a built-in oscillator, and a four-stage amplifier is employed between the pick-up and the indicating meter to amplify the measuring voltage.

In practice, the measurement is first made with the electronic gauge using minimum sensitivity and the next or final cut determined; then the pneumatic gauge, which is coupled to the tool rest of the lathe, is adjusted to zero. If the tool holder is now moved and the rise in height of the liquid column observed, a precise cut can be made. With this method a skilled operator can obtain close tolerances quickly and reliably. Final checking is then carried out using the electronic equipment at high sensitivity.

Fig. 25.

Electronic Surface Finish Comparator

There are several ways in which surface roughness can be expressed, and some countries in Europe as well as in the U.S.A. have adopted their own standards. The British Standard (B.S. 1134) is based on the average roughness height, centre line average.

An interesting electronic application by which surface roughness can be compared to this standard for use in production test departments, etc., has recently been developed.

The principle of this method is shown in Fig. 26. It consists of a pick-up of the piezo-electric type, which is traversed across the surface of the article by hand; this pick-up is coupled to an attenuator feeding an electronic valve amplifier. The rectified output from the amplifier is fed to an indicating device, which is directly calibrated to give the average roughness height. Adjustment of the attenuator allows a meter scale length equivalent to four times full-scale deflection, i.e., a total of 12 inches.

In order to calibrate each range of the instrument, four roughness standards are provided with surface finishes ranging from 125 micro-inches to 2 micro-inches. The surfaces of these standards are covered with a very thin and extremely hard chromium layer, which does not influence their roughness values, but enables them to retain their standard of roughness for some considerable time, dependent on the use to which they are subjected.

The measurement of surface roughness is made by moving the pick-up in the direction perpendicular to the machining marks on the surface at a scanning

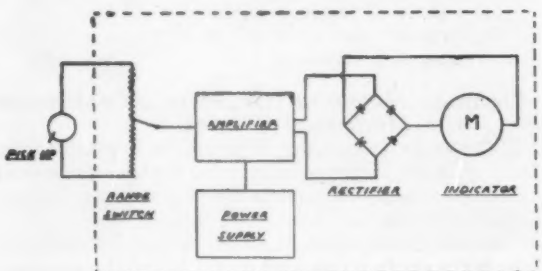


Fig. 26.

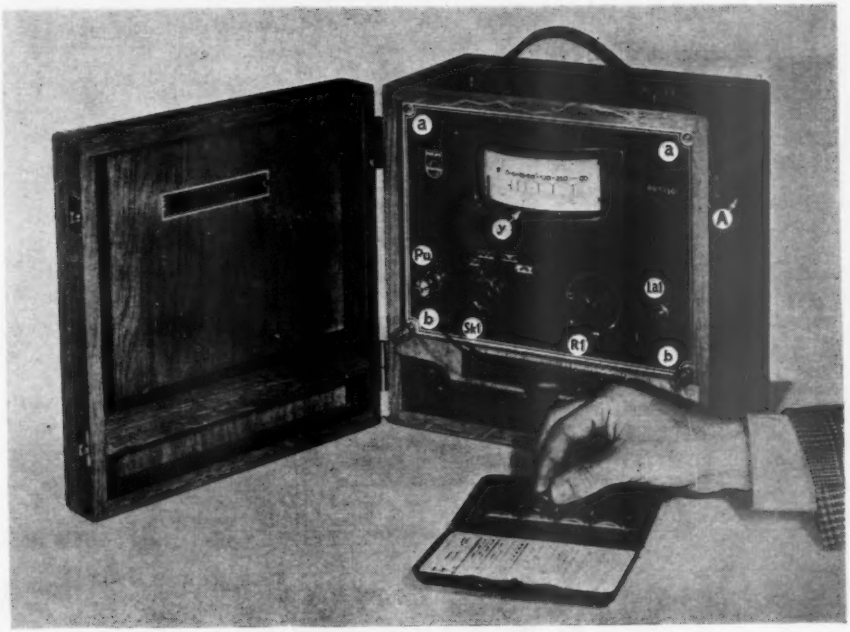


Fig. 27.

speed selected to give a stable and reproducible reading on the meter.

Fig. 27 shows the complete instrument with the pick-up and case, holding the four standards, in the foreground.

Industrial Television

One of the most interesting uses of electronics is in closed circuit television. This closed circuit equipment is eminently suitable for observation of production processes, of power plants, for foundries, etc. It is much used in cases of inaccessibility or where danger to personnel is apparent.

Such a closed circuit equipment consists of two parts :-

1. the camera containing a super-iconoscope type of tube, which gives high definition with a very great sensitivity;
2. a monitor display unit which also supplies the necessary voltages for the camera.

The camera is linked to the monitor by a length of cable which can be up to 300 ft. long without correction circuits, and up to 750 ft. long with correction; beyond this length the quality begins to suffer. A big screen projector can also be used in conjunction with this installation so that the picture can be observed by a large audience.

A normal type of lens such as is used on a standard 16mm. cine-camera can be employed, but usually three lenses are supplied, namely :-

1. a wide angle lens—1 : 1.5, f=2.5 cms;
2. a normal angle lens—1 : 2, f=5.0 cms;
3. a telephoto lens—1 : 2.5, f=7.5 cms.

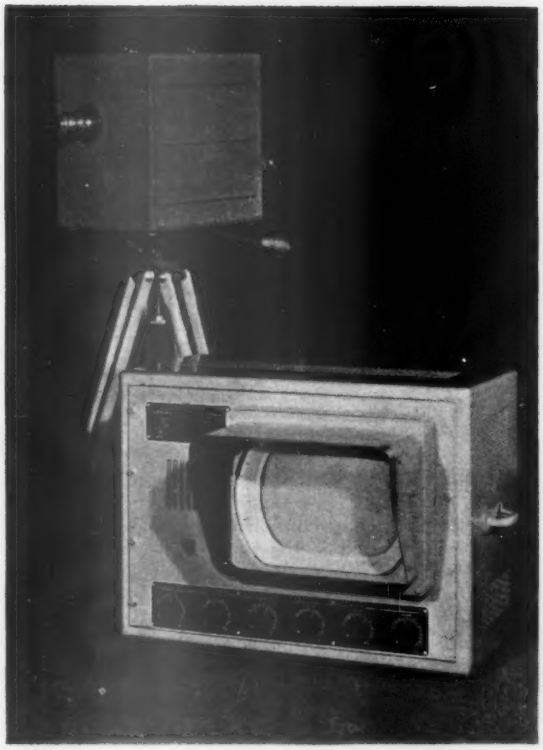


Fig. 28.

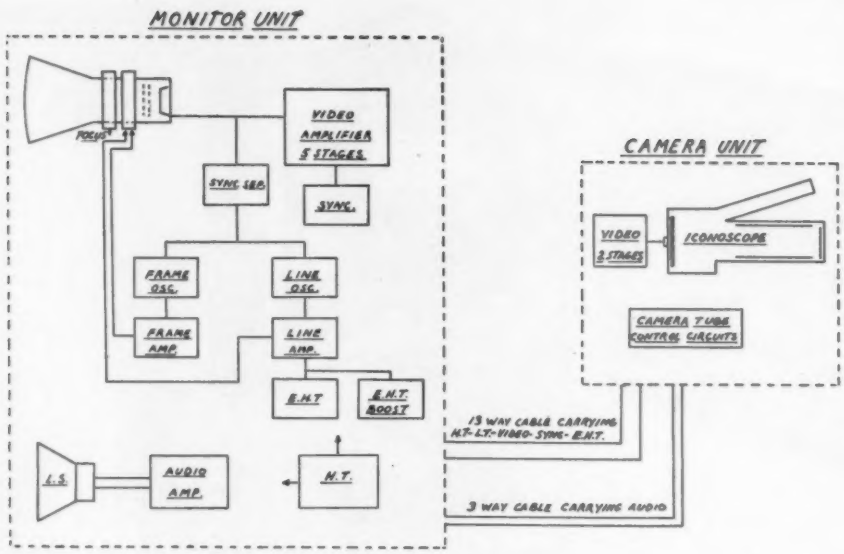


Fig. 29.

These lenses are easily interchangeable, the focussing and adjustment of the diaphragm being made on the lenses.

Fig. 28 illustrates the camera and monitor, while Fig. 29 is a block schematic of the complete equipment. This indicates that the monitor unit is similar in many ways to a domestic television receiver, but no interlacing is employed. The vertical scanning is synchronised with the mains frequency and the horizontal scanning is free running; the scanning frequency is equivalent to 300 lines.

The high voltage required for operating the cathode ray tube in the monitor unit is obtained by rectification of the fly-back time base pulses.

Conclusion

The Author hopes that the examples given have served to show a little of the practical scope of electronics in industry. Because of continuous rapid development, it is impossible to forecast the extent to which electronics combined with electrical engineering will be used in the future.

There is one point, however, which the Author would like to stress. Today there is far more electronic equipment available than there are trained personnel who understand its applications and can apply them to modern production problems. More education is desirable; far too often electronics is regarded as something very special and not as a logical part of the electrical engineering industry. It is therefore encouraging to read that King's College, Durham University, proposes to create a second chair in the electrical engineering department for the study of the applications of electronics to heavy electrical engineering problems.

The Author would like to conclude by thanking Philips Electrical, Ltd. for permission to prepare this Paper, Vauxhall Motors, Ltd. and Birlec, Ltd. for assistance with photographs and information and the Institution of Production Engineers for the privilege of reading it. The Author is also indebted to Messrs. S. F. Smith and D. C. P. Clinton for their valuable assistance.

BRITISH STANDARDS

The following Standards have recently been issued and may be obtained, post free, at the prices stated from the British Standards Institution, British Standards House, 2, Park Street, London, W.1 :-

B.S. 2573 : 1955. Report on permissible stresses in crane structures (4/-).

B.S. 2584 : 1955. Ratchet screwdrivers (2/6).

TRAINING IN WORK STUDY

with detailed reference to the Case Study Method in Applied Work Study.

by JOHN PURCELL, A.M.I.Prod.E.

Department of Aircraft Economics and Production,

College of Aeronautics, Cranfield.

A BRIEF survey of the organised training methods and subjects offered in a great number of engineering courses reveals similarity both in methods of teaching and subjects which, taken together, constitute the course. The deviations which exist will be found, not in the methods, subjects or terminology, but in the time devoted to each subject and, hence, in the detailed coverage. Enquiring further, the reason for the deviations will be found to be necessary. They enhance the value of the training to meet local industrial requirements. For example, courses in general mechanical engineering, when taken in a ship-building area, will stress the subjects closely associated with marine work; a mining area will devote more time to subjects most useful in the mining industry. The duration of the courses, methods of training and terminology are found to be almost universally standardised.

The organised training which is available for students of Work Study shows no similarity in methods used, subjects treated, duration of courses, or terminology used. All vary or are differently interpreted.

Work Study Training

Under conditions which prevail today, Work Study Training may mean anything from a short spell assisting a practitioner in Work Study to an organised full-time course extending over a period of many months. The methods used and detailed coverage of the subjects comprising the course must inevitably be influenced by the period of training. As with training in many other branches of knowledge and human activity in industry, one finds the training offered within the factory, externally, and as a combination of both internal and external. Training in Work Study is offered in these three forms.

The externally organised courses in Work Study do not exhibit the endeavour to meet local requirements. An attempt to give a general course prevails. Valid reasons for this are clear to see, but one would expect that generalisation would lead to standardisation, especially in the scope of the subjects and terminology. This, however, is not so. We find some similarity in syllabus wording, but the order in which the subjects are treated and the scope of the subject matter are extremely confused. The text books on Work Study treat the study as an inseparable unit. They, too, generalise and lack standardisation. Many authors add a connotation of terms used. This is often found to be necessary for the intelligent interpretation of the work, an example of the confusion of terminology and interpretation being the reference to human fatigue. Most of the older works use the word fatigue, others R.F. (Rest Factor), another will use C.R. (Compensating Rest), while in another works P.A. (Personal Allowances), will be used. P.A. is often used for denoting Process Allowance, which has no connection with fatigue.

The Head of a well-known Work Study training school explains that the reason for dropping the word 'fatigue' is psychological. When discussing the subject with the worker, it is a harsh word which suggests that the operator should feel a state of fatigue, rest allowance suggesting to the worker that he is allowed a certain period of rest. This is no doubt an excellent idea, but in a profession where human psychology plays such an important part, surely the preferred wording should be accepted and put to the fullest use. This is not so; one can take a new work on the subject and the word 'fatigue' is used again.

The recent report of the committee assembled by the Institute of Cost and Works Accountants and the Institution of Production Engineers uses the titles Work Studyman, Work Study Practitioner and Work Study Technician when referring to one who practises Work Study. The confused wording of advertisements for workers in Work Study is correctly exposed but, when the report suggests the divisions

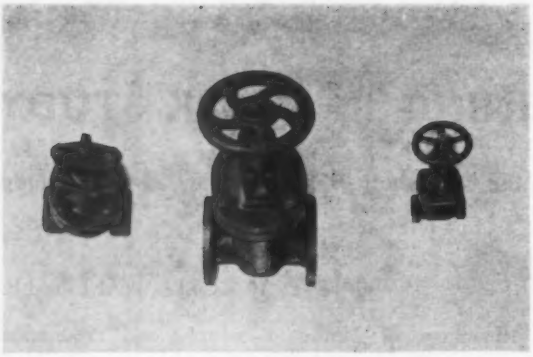


Fig. 1. A selection of steam line valves.

between the statutory levels within the Work Study profession, there is not the mark of practical thought exhibited. One would doubt that better divisions could be found than those into which the duties naturally divide themselves, i.e., that of the Methods Engineer and the Time Study Technician. This would also ease the problem of qualifications for in the former division, i.e., the Methods Engineer, a sound knowledge of the technical side of the trade in which he practises would be required. In the latter division of the Time Study Technician, a knowledge of industrial psychology and personnel management is desirable, a combination of both qualities being desirable for the overall supervisory grade.

The selection of examples for the practical period in Work Study training is not given sufficient thought in our Work Study Schools. One finds their work rooms packed with examples many of which present identical methods problems and call for similar operator qualities. The practice of allowing a student to bring an example of his choice does not produce good, generally interesting, examples which, at the same time, present a variety of basically different problems.

The examples for practical Work Study in an externally organised training school should be selected with a particular value in mind. Few examples will possess more than one or two really good features. Fig. 1 shows a selection of steam valves, the value of this example being that the size and weight of the components increase with valve size, shape, number and arrangement remaining constant. Fig. 2 shows an electric motor start control assembly, the example being chosen for the large number of component parts presenting a work station layout and operator learning problem. A further example would be the visual inspection of ball and roller bearings, stressing constant restricted focal attention.

For the external Work Study School, any example in which materials are not recoverable will prove costly. Such examples are: sawing wood, welding component parts together and cutting out material. These are best studied by visits to the place of manufacture.

Work Study and Management

That Work Study is a tool of management is not doubted by many, from those who manage down to the men on the shop floor. This description may be understood to indicate a very different thing from " just another tool ". The benefit to be derived from applied Work Study is a most controversial point at all the levels in industry. As with all other tools, there are the efficient and the less efficient. It is safe to say that of many tools (if this aspect of managerial control is correctly described by the word tool), Work Study can be one of the most valuable and effective, if backed by the complete confidence and enthusiasm of enlightened management. Conversely, the attempted application of Work Study by incompetent personnel with little or no managerial backing and appreciation may be the cause of unpleasant expensive disputes and rapid depreciation of labour relations.

There are many intermediates between the efficient and inefficient applications of Work Study in use at the present time. A contributory factor to the variation in efficiency may be primarily due to the enlightenment, enthusiasm and appreciation on the part of management, not the inadequate capabilities of the Work Study personnel. Before management decides to instal a Work Study section, or allow their personnel to be trained in Work Study, it may be assumed there is initial interest in Work Study. It is suggested that management become much more familiar with the subject and all it entails, especially the part which they must play and the continued contribution which must be made by management if the full benefits of applied Work Study are to be enjoyed.

With the above outlook in mind, the Work Study student must be taught the methods and techniques of scientific management both in his training period and in the initial period as a Work Study practitioner. The responsibilities which the Work Study practitioner is called upon to carry must be freely discussed throughout his period of training, every effort being made to give the student the opportunity to make the study of managerial methods and techniques required at first hand, particularly those which foster good relations between the different levels in industry.

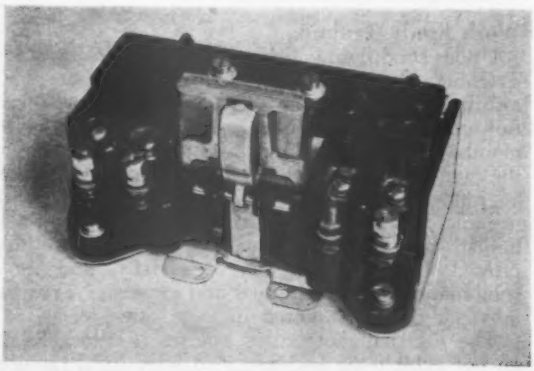
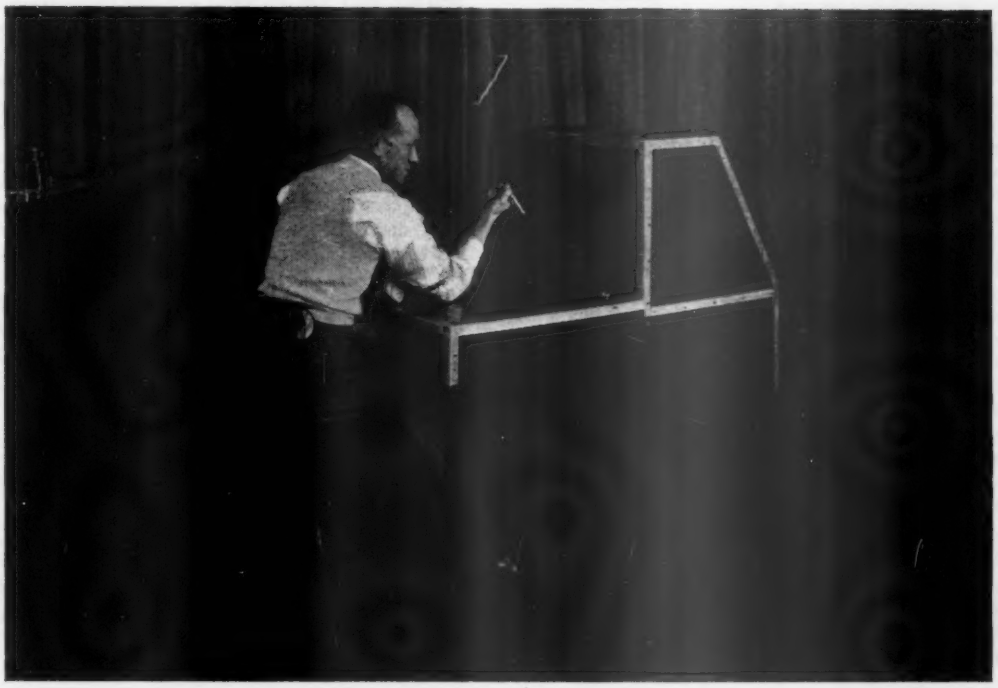


Fig. 2. Electric motor start control switch.

Fig. 3 (*Right and bottom of page*). An Ergograph.

The presentation to management of clear, concise, easily-assimilated information cannot be over-estimated in value. Work Study in practice makes conspicuous use of clear, simple, pictorial, graphical and tabulation methods to present information. The student must take a pride in this art, his work must be as international and precise as that of the engineering draughtsman.

When standards are accepted for presentation and methods, all concerned with Work Study must help to promote their establishment. The committee assembled by Mr. Hoover some years ago in the U.S.A., which found that more than 50% of losses in industrial production were primarily due to managerial defects, was one of the reasons for intensifying the search for methods and systems whereby improved control could be achieved. There is no reason to suggest that similar reasons exist today, but the close contact so necessary for successful managerial control is contributed to in no small part by the Work Study practitioner from the shop floor. This responsibility must be carefully studied by the student.



Management has long recognised the importance of the welfare of the worker and the environment in which he works. Ever since the Industrial Revolution many forces have made their contribution to this recognition. Such practical policies as those used by Cadbury Brothers, Rowntree's, Lord Leverhulme and those revealed by the recent Hawthorne investigations make it quite clear that the student must be given adequate opportunity to appreciate the benefits of such policies and their practical application. Labour turnover in these days of full employment can become a source of important losses; here the co-operation of the Work Study department can provide valuable assistance in the minimising of such losses. It is the direct responsibility of this department to study and record exactly every detail of the activities of the worker and the conditions in which he works.

Work Study and the Worker

The attitude, "Leave it to them, they will soon pick it up", was general in industry not so many years ago: that losses were suffered when a worker was first placed on unfamiliar work was realised. The methods used to reduce these losses often had their base in fear, and harsh threats. These conditions and methods are impossible in a modern society or industry; labour selection and training is practised in almost every factory. The work and reports prepared by the Work Study department are essential to successful training and often form the base of the training scheme. It is important, therefore, that the teacher of Work Study makes quite sure that a finished student in Work Study is competent in the analysis and recording of the information and assessment of the skills required by a worker to enable him to accomplish a set task.

Where training and proper introduction is given and recognised as necessary, it is an assurance to the worker when he is entering the factory for the first time, or as an established employee, for should he be asked to perform a task he has not met previously, he has confidence in that he has been selected for his suitability for the task and that help and guidance will be given.

The methods and techniques of establishing good relations between worker and Work Study personnel which create confidence and mutual trust cannot be over-emphasised during the training of the student, for unless Work Study is based on the goodwill of all concerned, it will prove of little value. Some training and study of industrial psychology will prove valuable to the student when he is in contact with the worker. Just as management must know beyond any doubt that the data and reports made by the Work Study personnel are completely reliable, so must the worker feel that the report on his job is made with him personally in mind.

The Broader Aspects of Costs and Work Study

Work Study reports and data are of value to management in securing effective labour, material, plant utilisation and information on which sound incentive systems may be based.

The usefulness of any report lies in the information it contains and the ease of extraction of the required facts. A report on costs of suggested or adopted schemes would be arranged in a convenient manner when prepared by one conversant with the requirements and terminology of Cost Accounting. It is not suggested that a thorough knowledge of Cost Accounting is necessary to a practitioner of Work Study as, in this capacity, he will be concerned with the value of work in terms of time. The evaluation of these times and their presentation in terms of costs and policy reports will come his way when he reaches a senior position. Sufficient study and practical work should be given in the limited related section of Costing, with further reading to prepare the student for a senior position.

The Work Study Department must apply its efficiency techniques internally. It must, in fact, show a profit as the other departments are expected to do. These profits will be derived indirectly from higher output at lower cost in the producing departments.

The Basic Introduction to Work Study Principles

The introduction to Work Study must be given to all concerned, supervisors, direct and indirect workers.

When the purchase of a new machine is being considered the inplace value, and often a training period of the operator, is taken into account, for it is realised that the machine will not make the expected contribution to the general scheme until it is installed and operating efficiently. Why simply buy a Work Study Department and expect its installation, acceptance and efficient working to follow naturally? Many of the adverse reactions to Work Study in the past would have been prevented had the installation value been budgeted for. This installation value includes the cost of frank and impartial discussion of Work Study with all concerned. There must be no mystery about it; no superior manner assumed by the Work Study personnel or any suggestion that something beyond the understanding of the common workman is to take place. The cause of any doubt must be found and remedied immediately it is suspected. All records must be open for inspection and explanation.

Only after talks and discussions have shown that the introduction of Work Study into the workshop is understood, and has been explained to all at first hand, should actual operation of the Work Study department commence. Motion economy and the natural movements will have been fully explained and when the operator is shown how to apply them in practice, he will co-operate and give any allowances, and standard time set, fair trial.

Fatigue

Equipment Used to Measure the Effect of Activity, Work Value and Rest Periods on Human Physical Fatigue

Many methods, and much equipment, have been used in the investigations which have been carried out to find a satisfactory way of measuring the effect of work on an operator.

The photograph in Fig. 3 shows an ergograph designed to record the value of work done by an operator when performing a set task. This value is recorded in units of foot or inch pounds of work done against a base of time. The work to be performed, the period of time over which it is performed and any rest periods between each cycle may be made constant. This allows a record to be made of the set task showing the total work done before the operator reaches a state of fatigue. The point at which an investigation is to commence may be set with ease, i.e., after a set period of complete rest. The conditions which may be present at the end of the investigation present the problem. Must the operator continue until he is incapable of further steady complete cycles, or until he is incapable of any part of a cycle, or should the operator be allowed to state his need for rest? In other words, he has reached a state of fatigue at which he would normally rest. This latter would appear to be best suited for practical purposes. Fig. 4 shows the force measuring platform on which the operator stands. Any effort made by him, while on the platform, will be resolved into its right-angled component forces and recorded in pounds against the time base.

Data recorded by the ergograph is confined to the effective work on the set task. With the platform, a record of all work, effective or otherwise, will be made. It is, therefore, essential when a work value investigation is made with the aid of the platform that only work which is necessary to complete the set task be performed, otherwise error will be introduced into the resulting record.

The Effect of Heat, Humidity and Noise

If it is necessary for a worker to be exposed to adverse conditions of this nature, their effects on his efficiency will be reduced by suitable periods of acclimatisation and generous relief periods.

Lighting

Except in the few cases where restricted lighting is necessary, there is no reason to ask anyone to work with inadequate lighting. One may read that the human eye is capable of adjusting itself to a certain extent to the lighting available. This should be of no interest here. Study should not be made of the results of inadequate lighting or to find the least level of illumination a worker can "manage with". The time will be better used in the study of examples of good lighting techniques. The training of the Work Study practitioner is not intended to produce heating, ventilation or illumination engineers. These problems will be better solved by the specialist whose services should be used.

Fig. 4. Dynamic force measuring platform.

The Case Study Method in Applied Work Study Training

The Case Study method may be successfully used in applied Work Study training, if the duration of the course is sufficient to enable the case to be developed and completed. The lower limit would appear to be a course of one hundred hours in which twenty-five to thirty hours are devoted to the Case. With this time available and careful selection of the example to be taken as the case, conditions which differ little from those which would be found in the factory can be presented.

A cross-section of the students who attend the general courses in Work Study shows they intend to practise in many widely differing industries, hence each will be interested primarily in the application and the basic principles of Work Study to his particular field of activity. To take a case: from the first introduction, develop and record the preferred method, and finally measure the value of the work involved per piece or cycle which will occupy the greater part of the time allotted to practical work. The case will contain but a few of the basic principles of Work Study. Hence, it is suggested that the students be grouped according to their primary interests and a case selected for each group which will present a first-class example and practical exercise in their particular field of activity. On the completion of this study, each group will

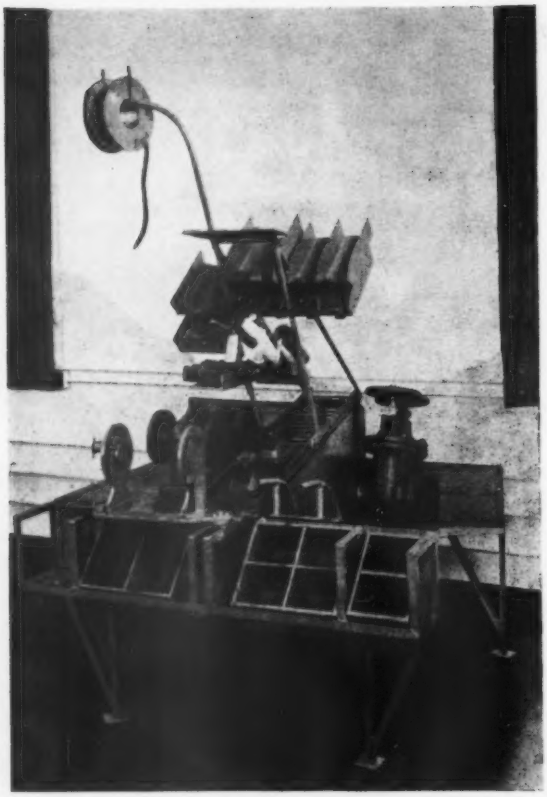


Fig. 5. 3" steam line valve assembly bench.

then study other cases in less detail, thereby covering examples of work involving all the basic principles of Work Study.

The Batch Number or the Number of Cycles to be Considered in the Case

The number of units, or cycles, to be considered in the case, is a most important factor. It is the key to the extent of the study by which it is possible so to restrict its field that the number would warrant little attention. Increasing the number demanded can present the problem at the following levels :-

1. manual methods with standard or simple tooling;
2. a study which will retain the manual methods throughout but with improved tooling;
3. some mechanisation of the tooling, work station and/or the improvement of any services;
4. more advanced mechanisation, the use of conveyors, feeder lines and the organisation which is essential to the efficient use of this equipment;
5. the demand reaching the upper extreme necessitating a highly mechanised or specialised plant. At this level, the practical study is beyond the capacity of any Work Study School.

Fig. 5 shows the specially-built work station which resulted from a case in which the demand for the 3" valve was set at 5,000 per month. This demand was calculated to present a marginal problem which was on the use of power nut runners, light conveyors or highly developed efficient hand tools, static work bench and manual trucking.

Introduction to the Case

The introduction to the Case must be clear and concise, the boundary or scope definite. The scope of the study will be different with each case. Many cases can be extended or contracted in harmony with, or inversely to, the number of units or cycles to be considered. This provides a further factor by the adjustment of which the example can be brought within the scope of the classroom or make a limited example wider in its scope and interest.

The Development of the Work Station and the Amount of Guidance Given by the Supervisor

The development of the work station will be directly influenced by the batch or number of cycles to be considered in the case. A simple short study will call for little or no help from the supervisor. As

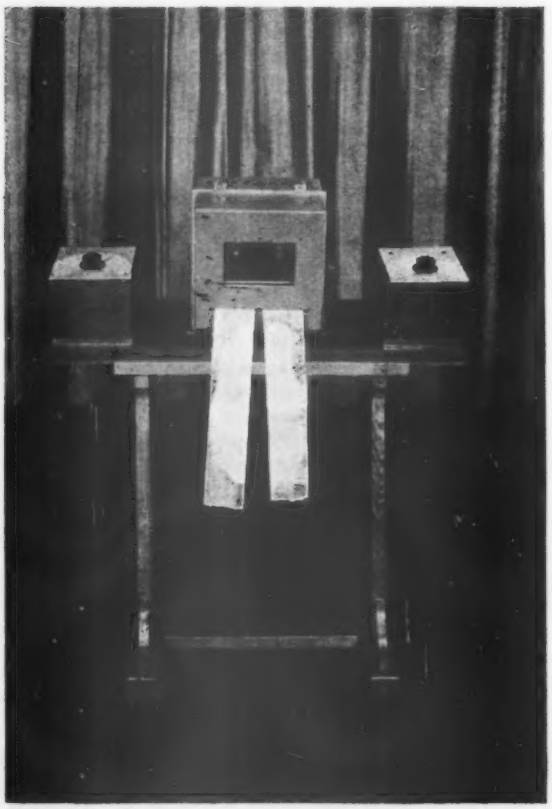
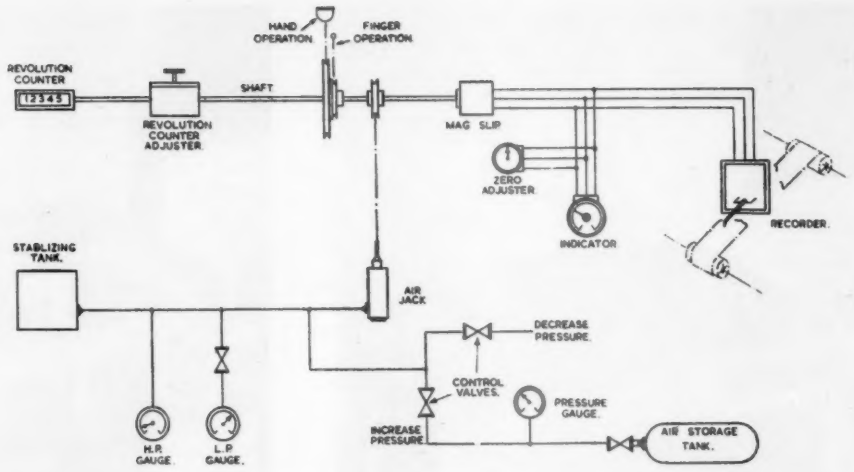


Fig. 6. The Rating Recorder.

Fig. 7.



SCHEMATIC DIAGRAM OF ERGOGRAPH-

the scope and number demanded increase, a specialist knowledge of certain unrelated subjects may be needed. Should no student in the group possess such knowledge, the supervisor would offer assistance in this subject. An example of this would be a group of non-engineering students considering a case of material inspection and grading. The case for any conveyor or mechanical equipment would be put by the supervisor acting in a consulting capacity.

Recorded Data on the Accepted Method and Equipment

The records made on the preferred method and equipment will depend on the scope and the extent of the study. They must be clear, concise and standard, limited to necessities and requirements of the case. Each student must make an individual record as far as time and economy permit. In many of the Work Study schools these records are made by the students when in the groups, with much exchange of figure and conclusion. This practice does not lead to vigilance and self-reliance in the student. Any exchange of ideas should be made in the time set aside for discussion of results and after they have been studied by the supervisor. All work sheets should be collected and checked. This will promote correct recording direct for the study and discourage rough notes which are afterwards re-written, as often the rewriting is altered ("cooked") to meet requirements.

Work Measurement

The Introduction to Work Measurement and the Equipment Used

There are bases against which work may be measured other than that of time but, for the purpose of this Paper, the base time will be assumed to be that most used in Work Study.

The most important reason for the use of time as the base is that it may be expressed in universally recognised standard units which are understood by most people who are concerned with work and Work Study.

The stop-watch may be used to measure time with sufficient accuracy for most purposes in Work Study. The student should be introduced to Work Measurement early in the course. He may then take every opportunity to practice reading the watch. Efficiency will be achieved with adequate practice. The progress of the student in the efficient use of the stop-watch will be assisted by the use of a simple apparatus which will give accurately timed visual signals at irregular intervals of time; in spare minutes, the student will record the times between the signals. He may check his readings with the actual times. A competitive spirit between the students adds to the interest of this training.

The timing of the actual performance of an operator will be taught at a much later stage in the course. By this time, the student must have become efficient in the use of the watch and recording the readings taken. When a record of an actual performance by an operator is taken the work may be carried out to standard requirements. In this case, the times taken together with any allowances will be the correct times allowed for the set task, or the standard time allowed per cycle, and will not require further adjustment. It is obvious that in practically all real situations the operator will perform at a varying pace, deviating either above or below the standard required. The most controversial points in Work Study are:-

1. what are the requirements to be met for a standard performance ?
2. how to evaluate the performances observed to obtain their actual value as compared with the accepted standard;

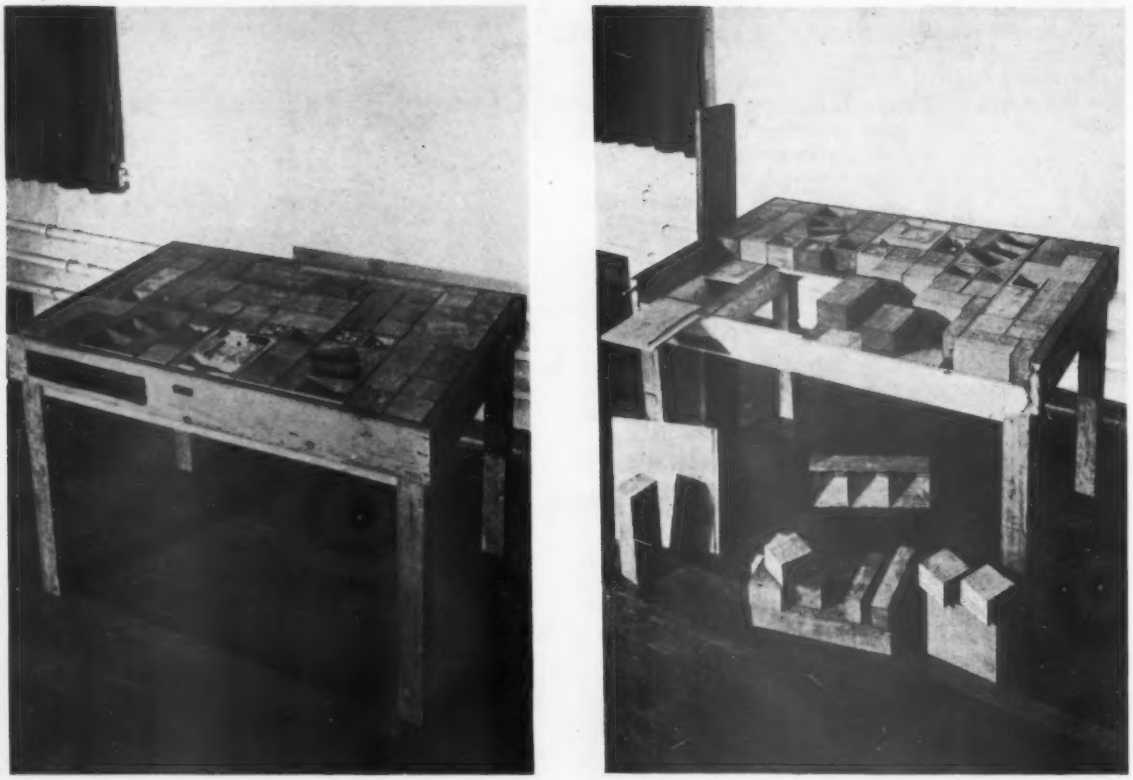


Fig. 8. The Universal Assembly Bench. The right hand photograph shows the view from the back, with clamp board and some blocks removed, showing the sliding section of the base board.

3. how to reduce this evaluation to a mathematical answer which will allow, if necessary, the adjusting of the actual times taken so as to give the value of the work in terms of standard time.

Until a standard for the adjustment of performances has been laid down and approved, it is difficult to comment here on this aspect of Work Study. Any suggested methods will need to be based on sound investigation and long trial periods in the many fields of possible application to Work Study. The student will be instructed in one or more of the methods which are in use which have proved useful. Rating has met these conditions and is taught in many of our Work Study schools.

Rating procedures can be divided into two main groups :-

1. those which are presented mathematically;
2. those which require judgment on the part of the Work Study practitioner.

Group 2 is the one most widely used. Taking the rating method in Group 2, it is obvious that, if the judgment on the part of the observer is required, there must be a sound training given to enable the student to give judgment to the required accuracy at all times when he is practising.

This training is assisted by the use of films which show work being carried out at a standard pace, and at paces other than standard. As with the recording of times, the student should make his record individually and only after his work has been checked should any discussions be allowed between students.

A very useful system of recording the rating assessments made by the students is by the use of the recorders shown in Fig. 6, Rating Repeaters. Each student has control of a recorder which records his assessment on a tape strip, and, at the same time beside the student's assessment and on the same tape a record is made which is correct for the example shown. The tape becomes visible two seconds after the record is made. Any mistake may then be corrected, but the student's progress in assessing the rate against the standard is shown.

Some Recent Developments in Equipment

The Ergograph

Work is done on the ergograph (Figs. 3 and 7) when the hand or finger grip is pulled from a point near the control cabinet towards the rear of the table. The resistance to the hand grip in the said direction may be varied from ½ to 250 lb. The hand grip is attached to the end of a length

of cord which passes under a constant angle roller and over a tangent wheel of suitable diameter and is secured at its other end to the piston rod of the air jack. The air jack is open to atmosphere at its inner end and supplied with air at the piston rod end. The air displaces the piston to its innermost position. This action draws the hand grip to the start cycle position. When a pull is made, the piston is displaced against the air pressure of the cylinder. The air is supplied from the air storage tank *via* an adjustable reduction valve (increase pressure) in the air line with the work cylinder is a large stabilising tank, its volume being 500 times that of the air jack piston displacement. By this arrangement the air pressure in the work circuit is maintained at a pressure which may be taken as constant for the application. To reduce working pressure, air is exhausted from decrease pressure valve to atmosphere.

Record of the work done is recorded in cumulative total in inch or ft. lb. in the revolution counter, which is controlled by the revolution counter adjuster gear. A graphical record is also made on the strip fed through the recorder, the pen of which is actuated by the mag slip and repeater unit.

The Universal Assembly Bench

The development of the work station is a very interesting part of a Case Study. During the development, the bins, tool supports and chutes will be rearranged many times before their most desirable position is found. The cost of material, labour and the students' time may be prohibitive to the tryout of such bin openings in the bench top for drop or chute dispatch. Often the benefits to be gained by these methods cannot be fully realised unless the installation is made. It was to overcome these difficulties that the Universal Assembly Bench was developed. This bench is so designed as to allow sunk bins and openings in the bench top, of any size, to be arranged in any position within the bench top area, at will, in a few minutes.

Fig. 8 shows the essentials of the Universal Bench, which has proved its practical value both in the classroom and industry where batch assembly is demanded.

The top of the bench is surrounded by three-inch deep boards to form a well. The base of the well is divided into a number of parts, of various widths, by the base section support members. These members are carried in slides in the frame of the bench which allows them to be arranged in any order of width. The base sections are cut into various lengths. By omitting one or more of the base boards an opening in the bench top is formed. The well is filled with Universal Blocks which are three inches deep; their width and length may be made in a variety of sizes to meet requirements of bins, etc., cut in the block. It will be seen from Fig. 8 that any bin or chute arrangement may be made and changed about at will. The bases of the blocks are flat. When the bin is not required the blocks may be arranged base uppermost and present a flat topped bench. When

Fig. 9. A further work station layout with photo cell equipment in the background.

Fig. 10. A general view of a Work Study room.

an opening in the top is needed, the uni-blocks are omitted over the area.

The back board of the well is arranged to clamp the blocks against the front board and so present a stable work surface.

(Patentee of the Universal Bench — J. Purcell, The College of Aeronautics.)

The Force Measuring Platform (Fig. 4)

Briefly, the equipment used consists of a platform which is suspended in such a way as to allow strain gauges to pick up a quantitative value of any displacement of the platform in its right angle component forces. The strain gauge display equipment interprets these values and presents them in the form of light spots on the cathode tube face. A further light source is arranged to give a flash at known intervals of time on the tube face. Records may be made by the use of the camera and film strip taking a continuous photograph of the tube face while the work is being performed.

As this equipment was developed as part of a recent thesis which is not yet published, further details should be sought from the Head of the Department of Aircraft Production, The College of Aeronautics.

NEW BUILDING FUND APPEAL

Since the publication of the last list, donations have been received from the following subscribers. (The list was compiled for press on 25th April, 1955).

Bombay Section:
J. R. Rudkin, Stud.I.Prod.E.
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ULTRASONIC TOOLS FOR HARD-TO-MACHINE MATERIALS*

by J. P. ALOISIO, Applications Engineer, and N. CLARK, JR.,

Research Division, Raytheon Manufacturing Company, U.S.A.

IN recent years equipments operating in a frequency range normally referred to as the sonic or ultrasonic region have been used in the solution of certain industrial problems. One such equipment is the Raytheon ultrasonic machine tool Model 500.

This equipment, operating at a frequency of 27 kc/s, is a new and unique device for machining materials which are hard and brittle. A few such materials are glass, ceramics, hardened steel, and tungsten carbide. The ability of the ultrasonic machine tool to drill accurately shaped and detailed holes has made it possible to satisfy such applications as the fabrication of drawing and blanking dies in a single carbide blank, the cutting of chip breakers, the drilling of ceramic spacers, ferrite cores, and a host of other applications in a variety of industries.

This equipment makes use of commercially available abrasives, has a low operating cost and can be operated by personnel who, although qualified, need not be extremely skilled. In operation, the Raytheon ultrasonic machine tool converts electrical energy into mechanical motion. This motion, present in the tool tip which is doing the cutting, is perpendicular to the work piece and varies between 0 and $\pm 0{\cdot}002$ in. at a rate of 27,000 times per second. Under these conditions, the tool tip is accelerated at a rate of from 100 to 150 thousand gravities. An abrasive suspended in some vehicle such as water is made to flow between this vibrating tool and the work piece.

Although the exact mechanism of the material removal is not known, the above accelerations imparted to the abrasive particles very probably have considerable effect on removing material. The rate of material removal is a function of the amplitude, the grit of abrasive, the mixture of abrasive, the pressure applied, the tool tip material, and the work piece itself. The shape and dimensions of the hole or cut produced are functions of the tool used and the techniques employed.

Principles of Ultrasonic Machine Tool Operation

Raytheon ultrasonic machine tools consist of an electronic power supply, transducer, supporting stand, work holder, and abrasive circulating system.

In its operating principle, the ultrasonic machine tool is an old solution with a new approach. Assume that a certain caveman desired to produce a hole in his flint stone axe with a copper punch. His procedure was to spread an abrasive harder than the flint over the stone and strike with the punch the spot where the hole was desired. The harder abrasive chipped the surface of the stone. If the supply of abrasive was maintained and enough blows were struck, a hole would eventually be produced in the flint.

With the ultrasonic machine tool, the equivalent of the punch may be held very rigidly and positioned very accurately. The shape of the punch may be extremely complex and many times more blows may be struck in a given period of time. If we assume that the hole our caveman made required a million blows of his punch at the rate of one per second, it would take him 280 hours to finish his axe. The ultrasonic machine tool could do the job in 37 seconds, or at the rate of 27,000 blows per second.

The ultrasonic power for this operation is generated in the electronic driver equipment in the form of electrical energy and fed to a transducer to be converted into ultrasonic energy. The cutting tool on the end of the cone is made to vibrate up and down parallel to the cone axis at the rate of 27 kc/s. With abrasive flowing between the vibrating tool and the work piece, cutting action will result when the tool is lowered on to the work piece.

Electronic Driver.—The electrical power supply for the transducer consists of a conventional oscillator and power amplifier capable of 500 watts output at 27 kc/s. A simplified schematic of this electronic driver is shown in Fig. 1.

The oscillator section utilises tubes V1 and V2 in a push-pull electron coupled circuit. The power amplifier consists of the push-pull triodes V3 and V4. The oscillator frequency is controllable in the range of 20 to 30 kc/s.

**Presented at the Twenty-Second Annual Meeting of the American Society of Tool Engineers, at Philadelphia, Pa., April 26-30, 1954, and reproduced here in slightly abridged form by kind permission of the Society.*

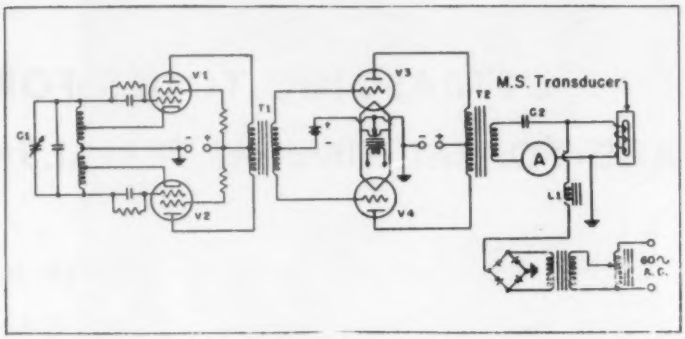


Fig. 1. Electrical diagram for 500 watt electronic driver for Raytheon ultrasonic machine tool.

The D.C. polarising supply, which is part of the electronic driver, supplies a bias current to the transducer. This bias current adjusts the amplitude so as to control the rate of penetration in any given material. The control for this bias current is located on the front panel and is marked " Power."

The electronic driver has been designed to operate on a 110 V. single phase 60 cycle line. At full power, it draws approximately 15 ampères of A.C. current. The input under these conditions is approximately 1·5 Kw.

Transducer.—In the mechanisms of operation, the electrical output of the electronic driver is converted into mechanical motion. The device which forms the bridge between electrical and mechanical energy is the transducer. The interior of the transducer is shown in Fig. 2. Attention is called to the extremely simple and rugged design and the tool cone which is attached below the flange. The upper part with the coils of wire is called the stack and is the source of mechanical energy. All other parts of the transducer are for support or for transmitting the ultrasonic energy to the work piece

The stack is composed of a pile of pure nickel laminations free at one end and brazed to the transmitting cone at the other. At the outer edges of the support flange, the cylindrical cover is bolted on water-tight. During operation, considerable heat is developed by magnetic and mechanical hysteresis losses. Cooling is effected by a water spray which is carried out from the bottom by gravity.

Magnetostriction

To understand how the transducer converts electrical energy into mechanical energy, it is first necessary to realise one of the fundamental properties of nickel, namely, that when a magnetic flux is set up in, say a rod of nickel, the rod actually changes its physical length. The mechanism of this energy conversion, which is called magnetostriction, is not completely understood, but it is a well-known property of nickel and several other metals and alloys.

The magnetostrictive properties of nickel may be determined by measuring its change in length for various flux densities. A curve may be plotted on linear coordinates as in Fig. 5, illustrating the fundamental relationship between the electrical and mechanical energies involved.

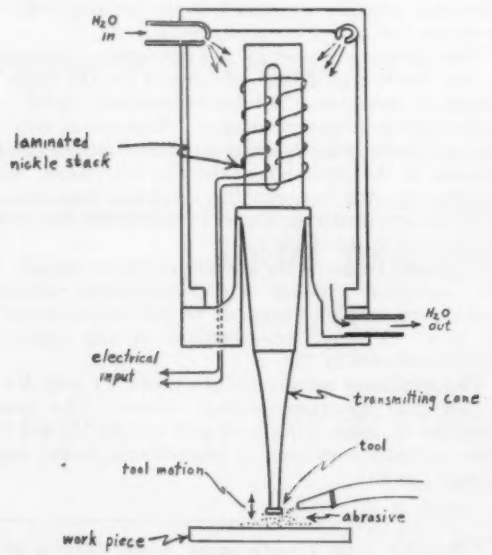


Fig. 2. Assembled electromechanical transducer for Raytheon ultrasonic machine tool.

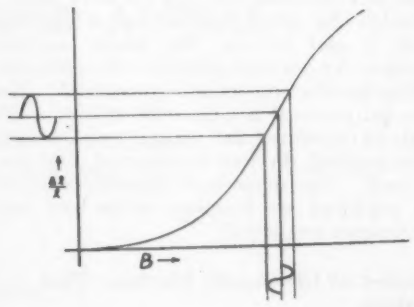


Fig. 3. Change in length of nickel rod (vertical ordinates) with change in flux density B.

As the current is increased through a coil of wire wrapped around a nickel rod, the flux density in the rod increases. This causes the nickel rod to shorten its physical length according to the curve of Fig. 3. It should be noted that at first, the change in length of the rod per unit length $\Delta L/L$ takes place very slowly with changing flux density B. The slope increases to a maximum, however, and then begins to level off again at high flux densities. For nickel, the upper knee in this curve occurs at approximately 6000 gauss and gives barely 30 parts per million change in length. It is clear that maximum efficiency or maximum change in length per unit will occur at the steepest slope on the curve. If now a bias flux of amount B_0 is applied by means of a direct current through the coil, and an alternating current is superimposed, a varying flux density of amount $\triangle B$ will be set up in the nickel rod. A corresponding alternating change in the length of the rod will occur.

Electromechanical Coupling

Electrical energy in the form of current through a magnetostrictive coil is not all stored in the magnetic field ; part of it is stored in the mechanical stress of the bar. The stored mechanical energy is available at the coil terminals just like the stored magnetic energy. In other words, a mechanical stress in a magnetostrictive bar can also generate an electric current in a coil around it.

The mechanical vibrations thus set up in the bar by the alternating current react back on the alternating current and modify it. In other words, the mechanical impedance is reflected back to the electrical terminals of the transducer. It turns out that the reflected impedance is a condenser and inductor in parallel. The inductor corresponds to the effective mass and the capacitor to the stiffness of the system.

An important criterion in the choice of magnetostrictive materials is the relative amount of energy stored in mechanical form as compared with the total electrical energy input, or the relative size of the reflected mechanical reactance as compared with the total electrical reactance at the transducer terminals. For nickel, this figure is about 25%, which is extremely good compared to other metals at comparatively low flux densities.

The complete equivalent circuit is shown in Fig. 4. Mechanical properties determine the value of C_M and L_M. The resistance R_M constitutes the mechanical load. A perfect transformer with coupling coefficient k determines the electromechanical coupling coefficient. The values L_c and R_c are fixed by the inductance of the electrical coil and its losses.

Resonance

Since the equivalent circuit contains inductance L and capacitance C in parallel, we can expect resonance to occur at some particular frequency. A mechanical analogy here is the familiar simple harmonic oscillator composed of a weight suspended on a spring. If a sinusoidal force is applied to the weight, maximum displacement of the weight corresponds to the resonant frequency. In the nickel

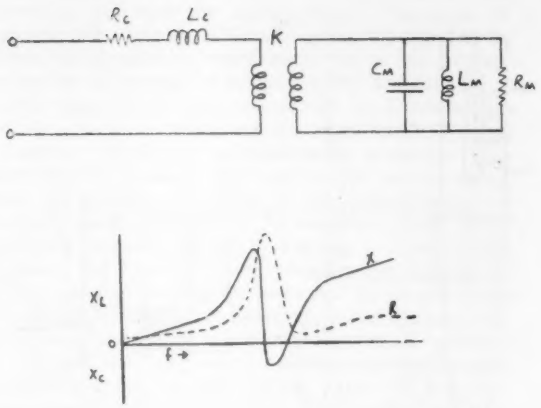


Fig. 4. Lumped equivalent magnetostrictive circuit of transducer.

stack, the mass and stiffness corresponding to the weight and spring are distributed and the condition of resonance takes on the same meaning as when dealing with electrical transmission lines. In fact, the differential equations describing the propagation of an elastic wave in a medium are exactly analogous to equations describing electromagnetic propagation. The inductance per unit length may be made to correspond to mass per unit length and the capacity per unit length to the stiffness per unit length.

If we now consider the nickel stack isolated in space and a current suddenly passed through its coil, an elastic shock wave will be propagated toward each end of the stack. At the ends of the stack, reflection will occur and the elastic wave will continue bouncing back and forth. If the current in the coil is turned off and on, or varied at just the right frequency to augment and reinforce the reflected elastic wave, the wave will continue to increase in amplitude until limited by some non-linearity or dissipation in the system. This is the condition of resonance.

As a result of this phenomenon, the change in length of the stack as given by the static condition of Fig. 3 may be increased many-fold. This is analogous to the increase in circulating current in a parallel tuned LC circuit and is proportional to the Q of the circuit, or the ratio of the reactance to the resistance. The effective Q of the nickel stack in this particular transducer is about 100, so that vibration amplitude of 100 times static values may be obtained at the resonant frequency.

Relative Motion of Transducer Parts

After the ultrasonic mechanical motion has been generated by the nickel stack, some means must be used to couple the ultrasonic energy efficiently to the work-piece and hold the assembly securely without materially damping the vibrations. How this is accomplished in the ultrasonic machine tool transducer is shown in Fig. 5.

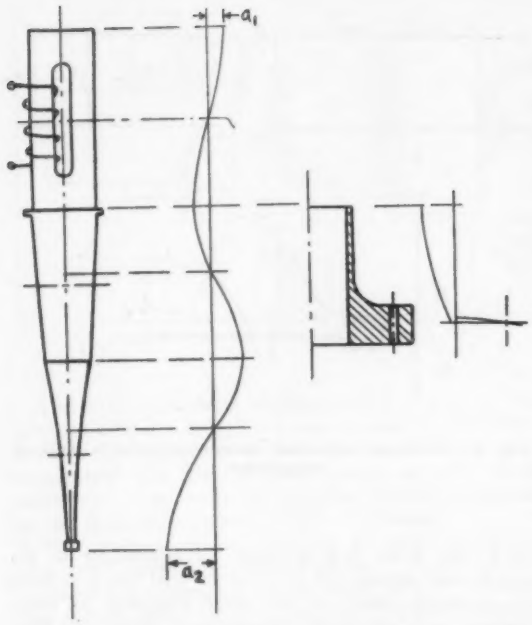


Fig. 5. Relative vibration amplitudes of motion in transducer parts.

If first the stack alone is considered, vibrating at its natural resonant frequency with no external force, the centre of gravity does not move relative to our reference, but the two ends do. To do this, the two ends must, of course, move out of phase. The relative motion is plotted just to the right of the mechanical assembly (Fig. 5). The vertical coordinate corresponds to distance along the axis of the mechanical assembly and the horizontal coordinate corresponds to displacements due to vibration along the axis, or what will be called longitudinal displacement amplitude. Right of the zero line may correspond to displacements up, and left, to displacements down.

At a particular instant of time when the longitudinal displacement amplitude is maximum, the relative phase of the displacement is as shown in Fig. 5. The centre of the stack has no relative displacement, while the two ends move in opposite directions an equal amount. The distribution of displacement gives the term " half-wavelength " to the physical dimensions of the nickel stack. The half wavelength may also be defined as in electrical transmission lines as

$$\frac{\lambda}{2} = \frac{v}{2f}$$

where v is the velocity of propagation of the elastic waves, f is the frequency and λ is the wavelength.

By attaching a full-wavelength rod to the nickel stack, the ultrasonic energy is made available at the cutting tool. As shown by Fig. 5, the tool is made to vibrate with a longitudinal displacement of a_2. The lower half-wavelength of the cone that transmits energy from the stack to the tool is removable so that different-sized tools may be used.

An adequate support for transducers has always been a major problem ; however, a satisfactory solution has been devised and is incorporated in the ultrasonic machine tool transducer. It consists of what is termed a quarterwave stub support in electrical transmission line analogy. The cylinder and flange brazed to the top of the transmitting cone (Fig. 2) is $\frac{1}{4}$-wavelength long. As shown in Fig. 5, the top half cross-section of the support is vibrating at the same amplitude as the nickel stack ; but at the bolt circle, where the transducer assembly is mounted, the vibration amplitude is minimum. Thus, a negligible amount of ultrasonic energy is lost to the support even though the latter is very rigid.

Use of Mechanical Transformers

For effective cutting, it is desirable to use as much of the ultrasonic energy as possible in removing material. Studies have shown that, to do this, as large an amplitude as possible must be present in the cutting tool.

The magnetostrictive transducer used in the ultrasonic machine tool is capable of supplying large forces, but at relatively small amplitudes. Since the cutting load requires small forces at large amplitudes, it is necessary to have some kind of transformer between the magnetostrictive transducer, nickel stack, and the cutting tool. This transformer must convert the energy available at the transducer to a form in which it can be readily used. The transformer used takes the form of a solid metal rod connected at one end to the transducer and at the other end to the cutting tip. The amplitude of vibration is now a function of the diameter of the rod. The smaller the diameter, the larger the amplitude. This means that in operation the larger end of the rod is connected to the transducer and the smaller end to the cutting tool.

It can be shown that amplitude is a function of the diameter by considering the kinetic energy at the magnetostrictive transducer.

$$\text{K.E.} = \tfrac{1}{2} Mv^2 \qquad (1)$$

where v is the displacement velocity and M is the differential mass across the transducer rod, that is :

$$M = dm = \rho S\, dx \qquad (2)$$

where ρ is the mass per unit volume, S is the area, and dx is the thickness of the top rod section. If we assume sinusoidal vibration of the amplitude, the amplitude is then

$$\xi = \xi_0 \sin wt \qquad (3)$$

differentiating gives the maximum velocity ($w\xi_0$) so that the velocity at the top is

$$V_t = W\xi_t \qquad (4)$$

The energy at the top may now be expressed in terms constant with respect to the transformer.

$$\text{K.E.} = \tfrac{1}{2}(\rho S_t\, dx)\ (\omega\xi_t) \qquad (5)$$

Since the metal transformer rod is composed of homogeneous material, ρ is the same throughout the rod. The differential distance dx is the same at the top and bottom and the frequency ω is the same.

This leaves S and ξ as variables, since the kinetic energy K.E. is assumed the same at the top and bottom.

Equating the K.E. at the top to the K.E. at the bottom, it can be shown that

$$\frac{\xi_t}{\xi_b} = \frac{\sqrt{S_b}}{\sqrt{S_t}} = \frac{\sqrt{\pi D_b^2/4}}{\sqrt{\pi D_t^2/4}} = \frac{D_b}{D_t} \qquad (6)$$

The ratio of amplitude at the top and bottom is equal to the inverse of the diameter ratios.

For the ultrasonic machine tool, it is necessary for reasons previously stated to operate the transformer at resonance. This means that the physical length of the transformer rod or cone is somewhat critical. It also means that the manner in which the diameters change is somewhat critical. The equation describing the propagation and reflection of ultrasonic waves in such a member are too complex for consideration here.

Tool Cone and Tool Tip

In the section on mechanical transformers, it was shown that there is an increase in amplitude as the taper or difference in cross-sectional area of the driver and tool cone increases. Also, for optimum operation, the cross-sectional area of the tool cone at which the tool tip is attached should match the cross-sectional area of the tool tip itself. Since amplitude is one of the factors determining the rate of material removal, it can be concluded that the rate of material removal will increase as the area of the hole being drilled decreases. Likewise, since the amplitude decreases as the cross-sectional area of the tool tip increases, it can be concluded that a limit exists in the maximum area that can be accommodated by the present model ultrasonic machine tool.

This limit in maximum area varies with the work material, that is, a larger area can be accommodated in glass than in tungsten carbide. In general, the limit in maximum area is approximately 1½ square inches.

It has been stated that the nickel stack, the driver cone, and the tool cone are all resonant ½ wavelengths designed to give maximum amplitude when tuned to the transducer frequency. Adding a tool tip increases the length of the tool cone such that its resonant frequency decreases. For optimum operation, the recommended procedure is to reduce the length of the tool cone such that the tool cone plus tool tip are properly tuned at the transducer frequency.

The material normally used for tool tips has greater losses than the cone material. This means that the overall efficiency of the tool cone and tool tip decreases as the length of the tool tip increases. This may impose a practical limit but, because of the number of variables involved, it cannot be clearly stated. For example, the limit may not be imposed by the length of the tool tip added, but rather by the rigidity of the tool or the ability of the abrasive to each cutting surface.

Abrasive

In operation, an abrasive transported in some vehicle such as water is made to flow between the vibrating tool and the work piece. The type of abrasive, the mixture of abrasive, and the manner in which the abrasive is made available to the cutting surface are all important factors in effective cutting.

The types of abrasive commonly used are boron carbide, silicon carbide, and aluminum oxide. These abrasives, which are commercially available and relatively inexpensive, are used in grit sizes ranging from 180 to 600 depending on the requirements of the particular application. In diameter, these abrasives vary between 0·0034″ to 0·00033″. Tests which correlate the type and size abrasive for maximum cutting rate in any given material have not been completed. In general, however, it has been established that the cutting rate of most materials increases as the grit size increases and that the harder the abrasive the higher the cutting rate. It has also been observed that the surface finish varies inversely with the grit size. Surface finishes with this method of machining have been measured at between 10 and 15 micro inches when using a 600 abrasive.

Feed of abrasive, stated generally, is that a fresh flow of abrasive must be available under the tool tip at all times. The techniques for accomplishing this vary considerably with the process being performed. In cored materials, it is recommended that abrasive be forced up from the bottom as well as having a stream directed at the cutting surface. In a trepanning operation, it is suggested that abrasive be applied both inside and outside the cutting tool. In applications where neither of these techniques is possible, a steady flow of abrasive can be maintained on the surface being cut by periodically removing the tool and permitting a stream of fresh abrasive to flush out any abrasive that might be trapped in the cavity being drilled.

A Cutting Procedure

An outstanding advantage of this machining principle is the simplicity of the tools required because they are merely the male counterpart of the desired shape. Even the most complex cavity in the hardest of materials represents a straightforward tooling operation.

The materials most frequently used for tool tips are cold rolled and unhardened tool steel. These materials based on present data represent a compromise in maximum cutting rate, minimum tool wear, machinability and availability.

Tool wear encountered with each of these materials varies considerably with the type of material being drilled and the amount of material being removed. In glass, the ratio of depth of cut to tool wear is as high as 50/1. In tungsten carbide, it may be only 10/1 or as low as 1/1. Tool wear, plus the fact that some side lapping results from the feed of abrasive down between the tool and work piece, requires that certain procedures be followed if high accuracies are to be maintained. Side lapping can best be visualised when considering the drilling of a blind hole.

It is obvious that all of the techniques developed cannot be stated here nor have they been developed for all applications to which this method of machining

(concluded at foot of next page)

NOTICE OF COUNCIL ELECTIONS 1955/56

NOMINATIONS

(a) In accordance with Article 43, nominations are invited to fill nine vacancies for elected members to serve on Council for 1955/56 (i.e. eight Members and one Associate Member).

(b) Before candidates are nominated for election, their consent must be obtained.

(c) Candidates for election must be nominated in writing by three *corporate members of the Institution.

(d) In addition to nominations as in (c) each Section Committee may nominate one candidate.

(e) **Nominations must reach the Secretary at 10, Chesterfield Street, London, W.1, not later than Thursday, 19th May, 1955.**

(f) The members listed below are due to retire and are not eligible for re-election as elected members until at least one year has elapsed.

Members :-

A. J. Aiers	F. J. Everest	C. Timms
H. W. Bowen, O.B.E.	R. S. Hind	R. H. S. Turner
A. G. Clark	A. L. Stuchbery	

Associate Member :-

B. E. Stokes

By Order of Council

W. F. S. WOODFORD,
Secretary.
May, 1955.

*Corporate members are :-
Hon. Members, Members or Associate Members.

"ULTRASONIC TOOLS FOR HARD-TO-MACHINE MATERIALS"—*(concluded from previous page)*

is applicable. In general, the following outline should be followed in drilling shaped or intricate holes.

Working with cored materials offers several advantages not only in that a fresh supply of abrasive can be maintained, but also in that it reduces the amount of material to be removed. Its use is recommended whenever the application permits.

In applications where a large amount of material is to be removed, it is necessary that several tools be used. It was mentioned above that tool wear and side lapping must be anticipated if high accuracies are to be maintained. Side lapping is compensated for by undersizing the tool used ior roughing. Undersizing should be in the order of 0·01″ to 0·025″. If several roughing tools are used, undersizing should be progressively smaller. Tool wear is compensated for by using an accuracy dimensioned tool for final sizing. Where a large amount of material is to be removed or extremely high accuracies are required, several undersized roughing tools should be used before final sizing. With this method of approach, accuracies of 0·0002″ have been obtained in blanking and shaped wire drawing dies fabricated in tungsten carbide.

Applications

The applications to which this method of machining lends itself are many and varying. Its ability to drill shaped holes in hard materials, either conductive or non-conductive, has stimulated thought toward the solution of problems in a host of industries. Initiative has in most instances been with the industry itself. A partial list of materials that have been successfully drilled by this method of machining is given below :—

Alnico	Granite	Silicon
Aluminum	Graphite	Sapphire
Glass	Hardened Steel	Rexalloy
Ceramics	Quartz	Tungsten
Ferrite	Ruby	Tungsten Carbide
Glass bonded mica	Stellite	Germanium

A few of the applications involving these materials are :—

Shaped drawing dies	Ceramic spacers
Carbide dies	Stamping punches
Hardened steel dies	Jewellery
	Quartz cutting

London Section Stag Dinner

The London Section Stag Dinner, held at the Connaught Rooms on 16th February, 1955, was well attended. The official guests were Mr. W. J. Morgan M.B.E., General Manager, Machine Tool Trades Association; Mr. W. F. S. Woodford, Secretary to the Institution; and Mr. S. Caselton, Assistant Secretary.

The toast of "The Guests" was proposed by Mr. R. Kirchner and replied to by Mr. Morgan, and Mr. Woodford responded to the toast of "The Institution", proposed by Mr. W. Core. Mr. R. E. Leakey, Section Chairman, presided at this function. Unfortunately, neither the Institution President, Sir Walter Puckey, nor the Chairman of Council, Mr. G. R. Pryor, was able to be present this year, and Mr. Woodford was asked to convey to Mr. Pryor the good wishes of the gathering for his speedy recovery.

As on previous occasions, the evening concluded with an excellent entertainment.

A Well-Kept Secret

Friends and colleagues of Mr. L. A. de Gebert, Associate Member, of Davey, Paxman, Ltd., Colchester, have been surprised to learn that Mr. de Gebert is, in fact, the Count of Noyan, and head of one of the oldest families of the French Touraine. When his uncle died in 1952, Mr. de Gebert automatically inherited the title, but did not reveal the fact until recently.

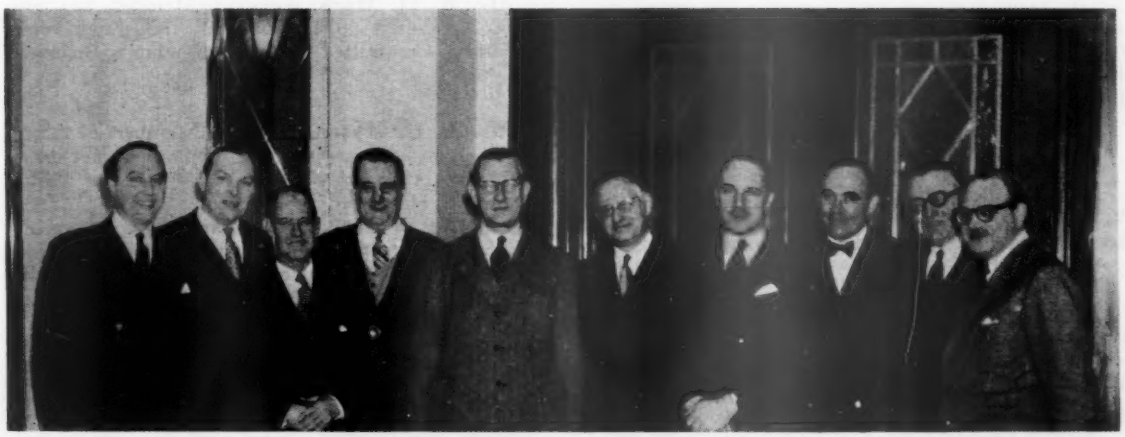
Documents which trace the family tree back to 1031 reveal that an ancestor was made Comptroller of Finances during the reign of King Charles VI, and from the start of the 15th century members of the family were a brigadier in the King's Army; a nobleman of the house of Prince de Conde; a page equerry to the King in 1683; and Provost Marshal of the Marshals of France in 1719.

Mr. de Gebert, who won a scholarship and first-class honours degrees in mechanical science and aeronautical engineering while studying on the Continent, wishes to revive the title, which has been in disuse for many years, in the hope that his young nephew will one day become the Count of Noyan.

JOURNAL BINDERS

The Institution is now able to supply the larger size of binder for loose copies of the Journal. Each binder will take twelve Journals.

Binders may be ordered from Head Office, price 10/- each, post free.



Some members of the London Section Committee with their guests at their annual Stag Dinner. From left to right are Mr. S. Caselton; Mr. W. F. S. Woodford; Mr. W. G. Marsden; Mr. W. J. Morgan, M.B.E.; Mr. R. E. Leakey (Section Chairman); Mr. R. Kirchner; Mr. G. R. Blakeley; Mr. A. L. Stuchbery; Mr. Wm. Core; and Mr. R. Hutcheson (Section Hon. Secretary).

news of members

Mr. C. X. Fernandez, Member, is now Superintendent of the Ordnance Factory, Katni, (M.P).

Mr. W. V. Hodgson, Member, has been appointed Assistant Managing Director of Wickman Limited. Mr. Hodgson joined the Company in 1947, and has been General Manager of the Machine Tool Division since 1949. He was appointed to the Board in 1953.

Mr. G. C. J. Legg, Member, has been appointed Deputy General Manager of the Cardiff Division of B.S.A. Tools, Limited. His practical training consisted of an apprenticeship on pumping machinery and aeroplane engines. Mr. Legg has served as a Planning and Machine Tool Engineer and during World War II, was seconded to the Machine Tool Directorate of the Ministry of Aircraft Production.

Mr. H. F. Spinks, Member, who joined Short Brothers & Harland Limited in 1951 as Machine Tool Engineer and became Chief Efficiency Engineer the same year, recently resigned to take up a new position with Sentinel (Shrewsbury) Limited, as Machine Tool Superintendent. Mr. Spinks served on the Birmingham Section Committee for many years and was Vice-Chairman of the N. Ireland Section Committee.

Mr. V. R. Winrow, Member, was recently appointed Chief Draughtsman to B.S.A. Tools, Limited. Previously Mr. Winrow served as Development Engineer and has been in the Designs Dept. of B.S.A. Tools, Limited, for 22 years. He served his apprenticeship with The British Thomson-Houston Company and was subsequently employed at Bean Industries Ltd., Alfred Herbert Ltd., and Ewarts Limited.

Mr. A. E. Ball, Associate Member, has now joined the Engineering Advisory Committee of the Reading Technical College. Mr. Ball has been a keen supporter of this work for some years.

Mr. J. M. Beattie, Associate Member, has recently taken up an appointment as Field Engineer with the Special Products Division of Canadian Westinghouse Company, at Hamilton, Ontario, Canada.

Mr. A. G. Jones, Associate Member, is now General Manager of Broom & Wade Limited, High Wycombe, and has been appointed to the Board.

Mr. W. J. T. Dimmock, Associate Member, formerly Works Manager of Hoover Limited, Perivale, was recently appointed Director and General Manager, Hoover (Washing Machines) Limited, Merthyr Tydfil. He joined Hoover Limited, at Perivale in 1933 as a supervisor in the toolroom and three years later he was made Tool Room Superintendent. In 1942 he became Production Manager, in 1944, Production Control Manager and in 1947, Assistant Works Manager. In 1951, he became Works Manager at Perivale.

Mr. Dimmock has visited the United States a number of times to study production methods, including a visit in 1949, when he was secretary of a specialist team sent by the Anglo-American Council on Productivity to study mechanical handling and mechanical aids. He has made a number of other visits overseas for similar purposes. Mr. Dimmock has served on the Editorial and Papers Committee of the Institution, and was the first Chairman of the Papers Committee following its reconstitution in 1952.

Mr. F. Kramer, Associate Member, has recently relinquished his position with Omes Limited, of Barnes, and has taken up an appointment with Duramin Engineering Co. Ltd., as Project and Development Engineer.

Mr. R. H. Mark, Associate Member, has now been appointed a member of the Engineering Advisory Committee of the Reading Technical College.

Mr. A. H. Mason, Associate Member, of B.S.A. Tools, Limited, was recently appointed Technical Manager, prior to which he was Drawing Office Manager. He joined B.S.A. Tools, Limited in 1932 and in 1944 became Chief Tooling Engineer, serving in this capacity until two years later, when he joined the Automatics Division of the Lockheed Hydraulic Brake Company as Works Manager. He returned to B.S.A. Tools, Limited in 1952.

Mr. C. M. Patel, Associate Member, has been transferred from the Ordnance Factory at Katni to the Ordnance Factory at Ambarnath, India.

Colonel M. Pratt, Associate Member, has now taken up duties as Military Attaché at the Legation of Israel, Rangoon, Burma.

Mr. J. M. Rattray, Associate Member, has now been appointed Works Manager of W. M. Still & Sons Limited, London.

Mr. K. J. H. Smith, Associate Member, who was Standards Supervisor of Canadian Arsenals Limited, has now been appointed as Production Methods Superintendent of the Company.

Mr. A. K. Thomas, Associate Member, has now been appointed Chief Designer of the Gear Hobbing Machine Section of Graven Brothers (Manchester) Ltd., Reddish, Stockport.

Mr. S. Wright, Associate Member, has now relinquished his position as Production Control Engineer with the Engineering Works Division of the Simon Engineering Group (Cheadle Heath, Stockport), and has taken up an appointment as Works Manager, with Bayles Brothers Drilling Company Limited, South Gosforth, Newcastle-on-Tyne.

Mr. C. M. Andrews, Graduate, has relinquished his position with Samuel Hodge & Sons Ltd., Rainham, Essex, and has now taken up an appointment with the M.O. Valve Co. Ltd., of Brook Green, Hammersmith, as Draughtsman Designer in the Machine Design Section.

Mr. L. L. Chadderton, Graduate, is now employed by C. W. F. Hamilton, Limited, of Christchurch, New Zealand, in the capacity of Jig and Tool Designer.

Mr. R. M. Cooke, Graduate, has recently left the Research Department of the Furniture Development Council and has taken up an appointment with Aluminium Laboratories, Limited, of Banbury.

Mr. M. Innis, Graduate, has recently taken up the position of Time and Method Study Engineer with Wilson & Mathieson Limited, Leeds.

Mr. D. Kitchen, Graduate, is still with the Rootes Group in the Diesel Engineering Division which has now been transferred from Humber, Coventry, to Tilling-Stevens, Maidstone.

Mr. G. F. Meades, Graduate, has recently taken up an appointment as a Plastics Engineer with the English Electric Co. Ltd., Luton.

Mr. M. Naddell, Graduate, has taken up an appointment with The Cleveland Hobbing Machine Company, Canada, as a Development Engineer.

Mr. L. H. Sanders, Graduate, has relinquished his position with A.E.C., Limited, of Southall, in order to take up the appointment of Design Engineer in the Central Research Department of The Morgan Crucible Co. Limited, London. In the April issue of the Journal, Mr. Sanders was incorrectly referred to as "Mr. J. Saunders".

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REVIEWS & ABSTRACTS

"Workshop Technology", Part II by W. A. J. Chapman. 2nd *edition. London, Arnold,* 1954. 331 *pages. Illustrations. Diagrams.* 15s.

The subject of Workshop Technology in all its branches is becoming increasingly important in the technical college curriculum. The recent establishment of this Institution's Associate Membership Examination has laid emphasis on this class of work, and teachers and students realise that there is much more to the subject than a certain number of hours spent in the workshop, coupled with lectures which merely describe various workshop processes.

Dr. Chapman's book is a useful contribution to the teaching of the subject and, to judge from the number of reprints since 1946 and the present second edition of the work, it has proved very popular.

Comparing the second edition with the first, there appear to be few major modifications, although in his preface the Author says that it has been necessary to replace certain diagrams and parts of the text. It is unfortunate that parts of the text in the first edition which could have been improved and corrected have not received attention in the second edition. These faults lie particularly in the field of gauging and measurement, and it would appear that the Author is more at home in the realm of machine shop practice than in the more specialised field of metrology. For example, although reference is made in Appendix 5 to the up to date edition of the British Standard on Limit Gauge Tolerances, there is no explanation of its principles or application in the text. Erroneous ideas are, in fact, put forward in stating that the inspection gauge is often made to accept work slightly nearer the tolerance limit than the working gauge, without explaining the essential difference in the disposition of workshop and inspection gauge tolerances, no reference at all being made to the new "General" gauge now specified. Referring to the measurement of a taper gauge with rollers, it is stated that two sets of rollers are necessary to measure the diameter of taper at two

positions. It is a well-known principle of measurement that unnecessary variables should not be introduced, and that the most accurate method of measuring tapers is to use the same pair of rollers at each position, thus eliminating possible differences in diameter which occur between two sets of rollers.

However, the book is quite comprehensive on the subject of machine shop practice, and workshop technology and deals in some detail with the construction, operation and tooling of various types of machine tools. A chapter on machine tools, which includes some details of alignment tests, is followed by chapters devoted to the lathe, shaping, planing, slotting and milling. A good deal of attention is paid to milling cutters and the calculations involved in speeds and feeds. Simple indexing is dealt with, but differential indexing has not been mentioned. A chapter on drilling and boring describes a number of machines, methods and tools in this class of work. The important subject of grinding is dealt with in two chapters which include details of wheel types and grades of abrasive. Methods of external, internal and cutter grinding are described, together with examples of machines in each category.

The book is well illustrated with some 289 photographs and diagrams, is well written and nicely produced. The Author does not hesitate to include useful advice, both in the form of workshop "wrinkles" and practical philosophy. His book has obviously been written with the youthful apprentice very much in mind, although this does not imply that the more mature reader will not find it useful. **K.J.H.**

"An Introduction to Cost Accounting", Vol III by R. Warwick Dobson. *London, Gee and Company, Ltd.*, 1954. 352 *pages. Illustrations. Diagrams.* £1. 17s. 6d.

This third and last volume of the series is mainly devoted to the forms and documents of costing, and many proprietary ones are illustrated. Unfortunately, a number of illustrations have been so much reduced that some of the forms cannot be understood without the aid of a magnifying glass, and a few parts are unreadable by any method.

The forms and documents are illustrated, the various copies are listed, and how each is used is explained, but to find out why a particular one is used the reader must generally refer to a previous volume. This is one reason why the present volume makes rather dull reading. Another reason is that the Author's systematic and objective style. which was attractive in the first volume, here results in the trees obscuring the wood. The volume could have been more interesting and more useful if the Author had adopted a critical treatment of his material.

Students will undoubtedly find this volume a useful introduction to the paperwork of costing, and anyone who is faced with the task of designing or redesigning forms will have no excuse for missing anything if he works with volume three before him.

Taking the three volumes together practically every facet of present-day costing is covered, but in the last two volumes (and particularly in the third one) the Author seems to go over a great deal of ground without saying anything very much on any one page, with the result that the reader finds it difficult to keep his bearings. Though one can appreciate why the Author decided to take his very involved subject completely to pieces and lay it bare over nearly a thousand pages,-it is this reviewer's opinion that he should have compressed the three volumes into two—or else he should have left more meat on the bones and spread them over an even greater area comprising four volumes. Nevertheless, the Author is clearly at home with his subject and anyone who follows him through all three volumes will have learned a great deal about cost accountancy. **C.H.S.**

"International Symposium on Automatic Digital Computation", No. 3, *Teddington,* 1953. *London, H.M.S.O.,* 1954. 296 *pages. Illustrations. Diagrams.* 21s.

In March 1953, a four-day symposium on Automatic Digital Computation was held at the National Physical Laboratory, Teddington. The book under review is a report of the proceedings of that symposium.

Thirty-eight papers are reproduced and these are conveniently grouped under the following headings:- British Machines, Programming, The Utilisation of Computing Machines, Circuitry & Hardware, Servicing and Maintenance, Medium Size Digital Computing Machines.

This book was never intended to be a popular work, but for those who specialise in this particular application of electronics it summarises a great deal of the development work that has been undertaken in several countries during the past few years.

There appear to be two aspects of this subject which could interest production engineers. Firstly, a description is given of a computor which has been made by a large firm of caterers for commercial calculations. In other words, this computor is intended to undertake a large number of simple calculations, (wages, invoices, etc.), at ultra high speed with virtually infallible accuracy. The second aspect has a direct bearing on the Institution's conference on the Automatic Factory, in June 1955. There appears to be little doubt that the automatic factory will contain a large amount of electronic equipment and the research work being undertaken with the running of these computors must help eventually towards greater reliability of these types of electronic equipment.

It is difficult to recommend this book to any particular class of reader, but any engineer with a modest knowledge of electronics could read it, and be interested. **S.R.S.**

"Realistic Depreciation Policy" by George Terborgh, *Machinery and Allied Products Institute,* 1954, *Chicago.* 197 *pages. Diagrams.*

This book follows the Institute's previous publications on related subjects—"Dynamic Equipment Policy", "MAPI Replacement Manual" and "Company Procedural Manual on Equipment Analysis". It is not an easy book to read, but perseverance brings its reward. The reader need not be frightened by the apparent abstruseness of the argument and complexity of the calculations. As claimed in the Introduction, nothing in the text demands any technical training beyond a knowledge of simple arithmetic.

One of the principal aims of the Institute in sponsoring this work is clearly to influence the Federal Government of the U.S.A. towards a "reform of tax depreciation which must stand high on the agenda of public policy". It is doubtful whether this aspect of the work will be of interest or value to any reader in this country, other than a serious student of taxation law.

The term "realistic" in the title is given a precise meaning as the opposite of "incentive" depreciation. The Author sets out to find a system of depreciation believed to be "approximately realistic", as a standard with which to compare the present system as found in the United States, where (as in Britain) the depreciation tax law largely dictates management policy in this field.

There is in the book, however, much of value to the practising manager and the accountant, as the following will show. The basic argument appears to be that any tax law which encourages industry to slow down its rate of write-off will inevitably bring about a reduction in capital resources and, further, that managements are reluctant to replace equipment which, because of a slow rate of depreciation, still has a substantial remaining book value.

This latter point is of striking significance to British managements. It is a known weakness of our equipment replacement policy that we continue to use, and hope to obtain good work from, plant which is old, or slow, or obsolete—and often all three ! We know that U.S. managements "retire" equipment much more rapidly than we do, and yet here is a claim that replacement in the States could well be much more frequent than it is.

By painstaking exposition, by table and chart, in the manner one has learned to associate with the erudite American, certain conclusions are reached.

Straight-line and other methods of write-off in common use are shown to be undesirable in a growing economy. The declining—(or reducing)—balance method, as widely used in Britain, is apparently only permitted by U.S. tax authorities at a rate no more than 1½ times the corresponding straight-line rate. To be attractive, and more nearly "realistic", it is argued that this must be raised to twice the straight-line rate. The proposal thus takes the resounding title of Double-Rate Declining-Balance Depreciation, and its use is put forward as the desirable aim of American managements.

By the reader, some knowledge of the American language is required. For instance, a recommendation that tax payers should be authorised to "blow up" original-cost book values, must not be thought to have any connection with gunpowder.

It is not really unfair to say that a simple, though scholarly, piece of work has been "blown up" into a full-length treatise in order to convert the (American) tax-collector. J.E.

"Hydraulic Operation and Control of Machines" by Ian McNeil. *Thames and Hudson,* 1954, *London.* 324 *pages. Diagrams.* £1. 15s. 0d.

The real purpose of this book is to blend together the theoretical and practical aspects of hydraulic operation and control of machines. It can be well recommended to students of engineering but would prove an asset in the library of all drawing offices, particularly those who have had little previous experience of hydraulic machines.

The book deals, in the first two chapters, with the introduction and historical survey of hydraulics as well as basic theoretical considerations. The next five chapters deal in turn with various types of hydraulic pumps, motors, valves, hydraulic circuits, accumulators, hydraulic fluids, seals and pipe couplings. The descriptive matter is most easy to follow and many diagrams and plates are provided to assist the written descriptions. Whilst the diagrams are as near as ever practicable to the book reference, this is not so with the plates and if this could be altered in a future issue, it would be to the reader's advantage.

The remaining chapters cover the application of hydraulics to forging presses, extrusion machines, deep drawing and stamping presses, application of hydraulic power to machine tools, moulding and die casting machines, mining and agriculture, aeronautical and machine uses, lifting devices and one or two miscellaneous examples, and finally the operation, care and maintenance of hydraulic plant and equipment.

The advantages and disadvantages of the various types of pumps are set out, although the Author quite properly presents facts only, since some equipment can be used to advantage in certain cases but may be totally unsuitable for others.

In a single volume the Author has possibly attempted to cover too wide a field, but he amply illustrates the great potential of hydraulic applications and provides a select bibliography to enable readers to find more detailed information. C.E.J.

"Manufacture and Properties of Steel Wire" . . . . ***translated from the German by C. P. Bernhoeft*** by Anton Pomp. *London, Wire Industry Ltd.,* 1954. 358 *pages. Illustrations. Diagrams.* [*Based on the 2nd German edition.* 1952.]

This book will appeal mainly to those concerned with the research and production problems of wire in its many forms, and who should, as a result, be fully conversant with the types of equipment used.

The main landmarks in the development of wire drawing are dealt with briefly and concisely.

Under the headings, "Fundamentals of Wire Drawing" and "Alteration of Properties of Material Through Wire Drawing", there is much of interest and value and, whilst everyone may not be in complete agreement with all the views expressed, they are presented in a manner which will without doubt, make the reader reconsider his own views where they are not in accord with those of the Author.

The chapter dealing with lubrication, though brief, clearly outlines the basic requirements of lubrication; but the present rapid advancement by the incorporation of additives to lubricants as a method of increasing efficiency, is perhaps, not sufficiently stressed. It is also unfortunate that this chapter opens with illustrations and comments on the full lock section of a locked coil rope in relation to the formation of a so-called "martensitic zone". This is highly controversial and many will not be in complete accord with the terminology and the suggested stage at which it occurs.

The chapters dealing with annealing, patenting, hardening and tempering are comprehensive and up-to-date, and summarise very ably the findings of many workers on this subject. There is much of interest, here, not only to the newcomer, but to the more experienced.

Galvanising is confined particularly to the more orthodox processes which are commercially available, but does not deal sufficiently with the metallurgical aspect of the matter, especially in connection with marine usage.

Wire testing covers the range of essential orthodox testing equipment quite adequately, but deals generally with tests which impose static, rather than dynamic, loads.

The chapter covering drawing tools is compact, but comprehensive, and includes up-to-date methods of testing dies. The Author has however, failed to mention the latest methods of shaping carbide dies.

To summarise, the work is reasonably comprehensive and suitable for the more advanced reader. J.B.

"Chromium Plating" by P. Morrisset, J. W. Oswald, C. R. Draper and R. Pinner. *Teddington, Middlesex. Robert Draper,* 1954. 586 *pages. Illustrations. Diagrams.* £3. 18s. 0d.

The practice of chromium plating is of increasing importance in many industries and to the production engineer. A great deal of information appertaining to the process is scattered among many different books and publications throughout the industrial countries of the world, and it has been the object to provide a text-book which collates this information in a single volume. A work of such magnitude could hardly be undertaken by one Author and, therefore, four distinguished Authors shared the writing and editing. The basic text was Mr. Morrisset's 'CHROMAGE' which was rewritten and widened in scope by its Author in collaboration with the three British co-Authors.

The text is divided into six parts dealing with the theoretical aspects of chromium electrodeposition, the technique of hard chrome plating, properties of hard chrome deposits, the industrial applications of hard chrome plating, decorative chromium plating and miscellaneous chapters including control of plating solutions, costs, health hazards and disposal of chromium plating wastes and regeneration of solutions. The appendix contains some useful tables. A most useful feature of the book are the references which contain over 400 entries from Great Britain, France, U.S.A., U.S.S.R., Germany, Japan, Switzerland, etc. The text is well illustrated and data provided by tables, charts and graphs.

The reader might find it difficult to digest this wealth of information as the book does not make easy reading,

but by anybody directly concerned with chromium plating or with its application, this work will undoubtedly be welcomed. It deals with the subject in the most comprehensive way and the treatise is well arranged.

A book of this nature will be read by many and used afterwards for reference to provide an answer or solution to the many problems connected with this subject.

A.W.K.

"Microscopical Techniques in Metallurgy" by Henry Thompson. *London, Pitman,* 1954. 146 *pages. Illustrations. Diagrams.* 18s.

The physical properties of metals such as weight and appearance are only a rough and ready guide to the strength of a material. However with the aid of a microscope it is possible to explore the crystalline structure of metals and see characteristic patterns of the basic materials and alloying elements. In this way, much valuable knowledge and experience about the structure of ferrous and non-ferrous materials can be accumulated.

Mr. Thompson, who is an Associate of the Institution, has had wide experience in this field and not only describes the microstructures of different metals but also outlines, in great detail, the best ways of selecting, mounting, polishing, and etching the specimens before examining them under the microscope.

He appreciates the value of making a record by photographing the microstructure in black and white or in colour and he includes numerous photographs (of specimens) magnified many times, with information as to the best ways of exposing the photographs and of developing, fixing and printing the negatives.

The book emphasises technique in strict accordance with its title and only touches the fringe of the science of metallurgy and the serious study of cause and effect in relation to the strengths of materials.

There are full bibliographies at the end of each chapter, and the book should appeal to engineers who are anxious to learn about the many materials with which they work.

J.L.C.W.

"Company Direction" by John Seymour. *London, Macdonald & Evans Ltd.,* 1954. 194 *pages. Diagrams.* £1. 5s. 0d.

This is not a text-book. As the Author makes clear in his Preface, it is an introduction to the responsibilities and duties involved in the direction of companies.

The modern trend, especially in the smaller and medium sized companies, is to have a strong constituent of executive directors on the Board. Consequently, we see more and more executives being elevated from the world of administration to that of direction. Too little preparation, if any, is being given to many who thus enter a new sphere of industrial experience. Although their new colleagues are usually ready with all the advice and forbearance at their command to smooth their path, so much is taken for granted.

If the single point is gained that the direction of a company's policy is not quite the same thing as managing the company, then time spent in reading this book is well spent.

Some space is devoted to the definition of functions and responsibilities. It is rightly pointed out that Company Direction is not an easy path, and courage is the quality which distinguishes a Board, and takes the company forward. Sooner or later, routine approaches to a problem provide no guide to the current action to take. This is the proving time for any Board and their decisions will either carry a company forward or backward.

Not least interesting to the reader is the chapter on the legal position of the director. An ignorance of the elementary knowledge of his responsibilities, the significance of his actions, and the range of his powers —there are many pitfalls leading to unexpected embarrassment later.

This book does not claim to contain an exhaustive study of all the legal and accounting aspects of Boards of Directors. Neither will the reader be able to dissect innumerable examples of different ways of running a company, and take his pick.

But under the heading "Objectives," the work touches upon the salient interests which will engage the attention of the novitiate—perhaps for the first time—namely, the respective budgets which should shape the immediate *management* policy in respect of sales, production, and finance, leading to the control of administration and profit budgets.

Altogether, this is a most useful and admirably clear introduction to a life of directorship, and by no means to be ignored by the experienced director.

A.G.

"Handbook of Standard Time Data for Machine Shops" by A. A. Hadden and V. K. Genger. *New York, Ronald Press,* 1954. 473 *pages. Tables.* **£4. 5s. 0d.**

This is essentially a book supplying—in a simplified form—a system of standard times attempting to cover the basic machine shop, welding and assembly processes. Its approach is by no means fundamental and no attempt has been made to state its relation with the wider and more detailed standard time systems such as "Work Factor", "Methods-Time-Measurement" or "Basic Motion Time Study", nor does it make any similar reference to the earlier work in this field of Gilbreth and Taylor, a mention in the preface excepted.

Whilst standard times are given to four decimal places of an hour, it is difficult to assess their validity, especially as when comparative tests have been applied to the more detailed systems mentioned above, considerable variation was found.

The advantages and uses of standard time systems generally which are given in the introduction cannot be accepted without qualification and presuming certain factory conditions.

The body of the book is segregated into fifteen parts, part one giving data and tables on machinability indexes, h.p. required, surface speed and r.p.m., Brinell and Rockwell conversion tables. Following this general chapter, each subsequent chapter deals with individual machining processes such as lathes, turning, drilling, milling, gear cutting, etc. No differentiation is made in the standard times for operating different makes of similar machine tools, except in the case of gear cutting. Each chapter gives examples in the use of the various data and tables provided.

E.C.

"Development of the Guided Missile" by Kenneth W. Gatland. *2nd edition. London, Iliffe & Sons Ltd. for "Flight",* 1954. 292 *pages. Illustrations. Diagrams.* 15s.

This, the second edition, is not only a complete revision of its predecessor, but has had many valuable additions. The book consists of nine chapters with three appendices.

After an excellent introduction, the Author commences by discussing the methods of propulsion, of which there are two main types, *viz*:- bi-propellant and mono-propellant, the workings of which are described by well laid-out explanation, drawings, graphs and tables. The second chapter on development deals with the various research establishments and their proving grounds. Ministry of Supply security reduces the amount of information available on British developments. The chapter on new armament deals mainly with the subdivisions in which missiles are used as defensive weapons, i.e. (i) rocket propelled fighter; (ii) the ground launched missile. Further ahead in development and potentialities is the "air to air" missile and a chapter is devoted to the methods by which these are carried and released by parent 'planes. After defence comes the offensive weapon, namely, the guided bomb and long range missiles.

Chapter 7 starts on the lighter side of rocket research, this comprising the potentialities of high altitude research into such phenomena as cosmic radiation, spectrum of the sun and physical conditions of the upper atmosphere, as well as an aid for meteorological reports. An absorbing chapter on space satellite rockets describes the type of design necessary for a rocket to reach the point where the earth's gravitational effects are such that the rocket could travel in free orbit around the earth. The possibilities of interplanetary flight are discussed, although development in this sphere appears to be limited. The appendix on telemetering deals with the transmission of scientific data from the travelling missile to earth. Appendix 2 comprises of photographic comparisons of the notable missiles, whilst Appendix 3 shows, in tabular form, the capabilities of these.

The book is very well illustrated throughout, and the Author's clarity of expression is of the standard into which all technical works should fall. Readers are given the opportunity of widening their knowledge of the subject by frequent bibliographical references.

The chapters which deal with the military uses and potentialities of guided missiles leave the reader with much food for thought as to the future, and the Author wisely states that the best defensive weapon we possess is the United Nations conference table. C.E.C.

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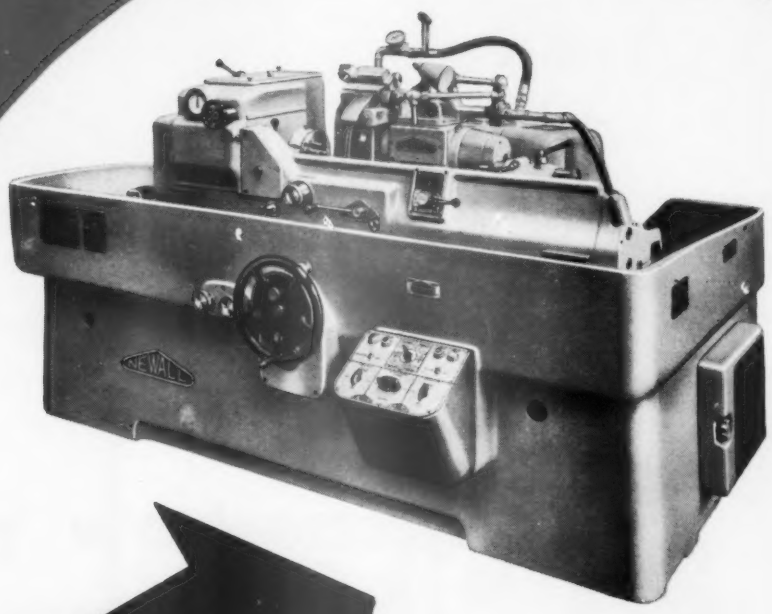

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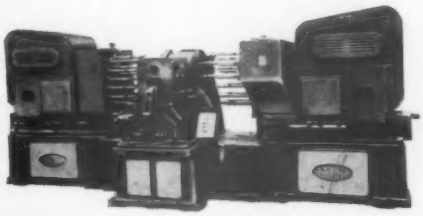

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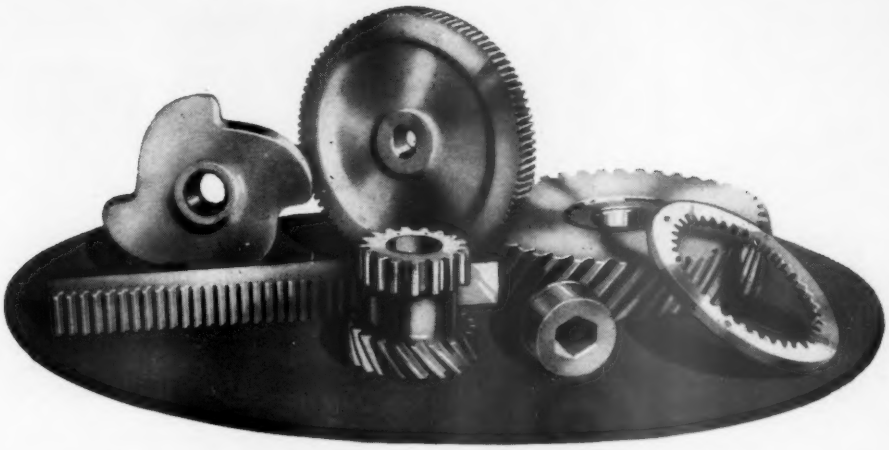
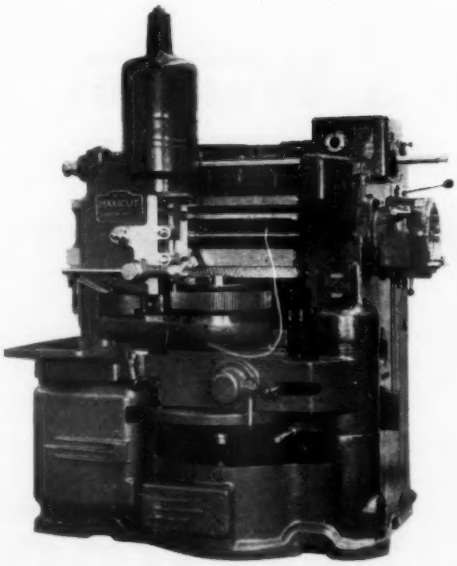


For highest production—



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MAXICUT Gear Shapers, installed in every high production plant throughout Great Britain, are responsible for the major portion of the nation's output of gears. A MAXICUT ensures high output, accuracy and adaptability.

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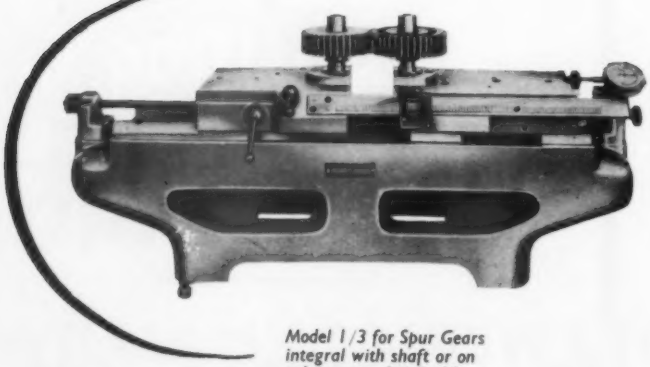
This highly sensitive, versatile unit checks centre distance, pitch line concentricity, and tooth form regularity with speed and accuracy. Suitable for spur, bevel and worm gears and worm wheels. This unit is to be recommended where gear production is sub-contracted.



Model 1/3 for Spur Gears integral with shaft or on arbors max. height 12 ins.

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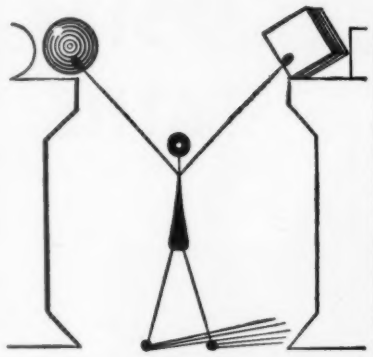
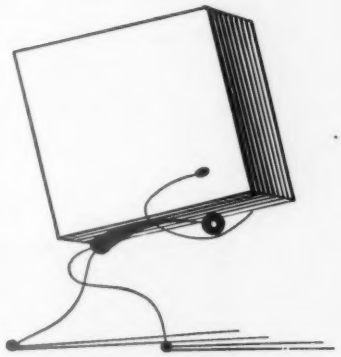
Hymatic Automation

IS THE NAME FOR MACHINES THAT

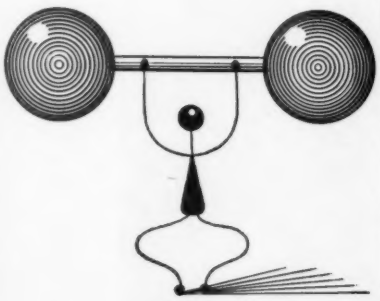


...reach...

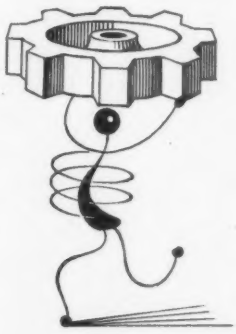
...grasp...



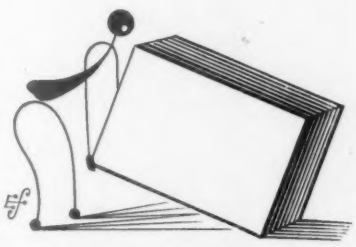
...carry...



...lift...



...turn...



...tilt...

... roll, dislodge, clean, sort, shelve, clamp and feed parts. Hymatic Automation is thus invaluable in the automatic and selective transfer of parts from one process to the next, from conveyor to conveyor; in unloading one machine and loading the next; or in quick clamping to hold parts during machining. All designs in Hymatic Automation are made for specific tasks, but are readily adaptable to others.

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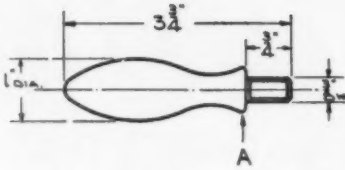

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STEM HANDLE

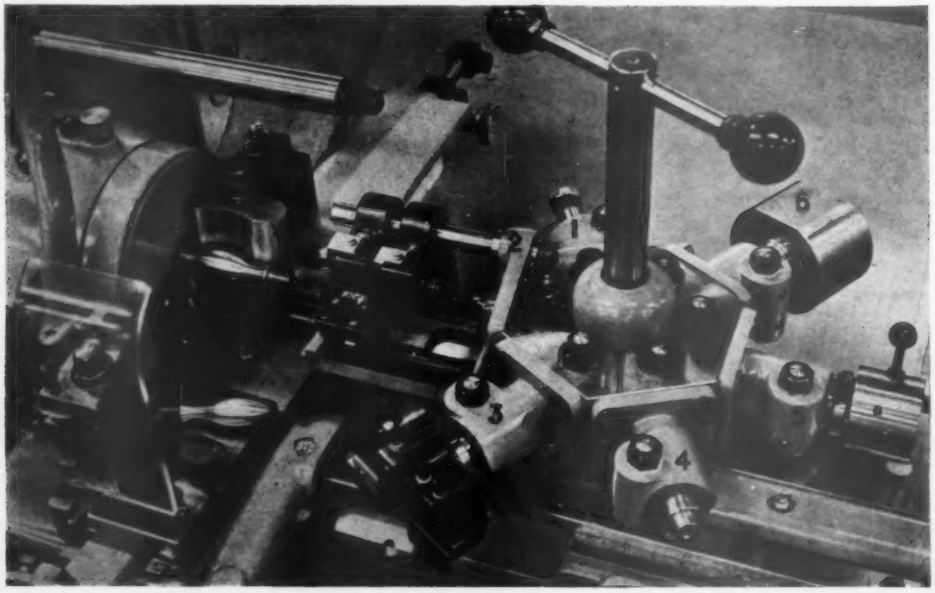
1" dia. Free Cutting Mild Steel Bar, En.1.

High Speed Steel Cutting Tools

Ward No. 2A CAPSTAN LATHE

Floor to Floor Time: 70 seconds

DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	* Feed Cuts per inch
	Hex. Turret	Cross-slide			
Feed to Stop and close chuck - - -	1	—	—	—	—
Multiple Roller Turn Two dias. A and ⅜" dia. -	2	—	2041	535	120
Roller End and Chamfer - - - -	3	—	2041	200	Hand
Support and Form - - - - -	4	Rear	605/95	160/25	Hand
Screw ⅜" Whit. - - - - -	5	—	605	60	16 T.P.I.
Support and Radius Part-off - - -	6	Front	605	60	Hand



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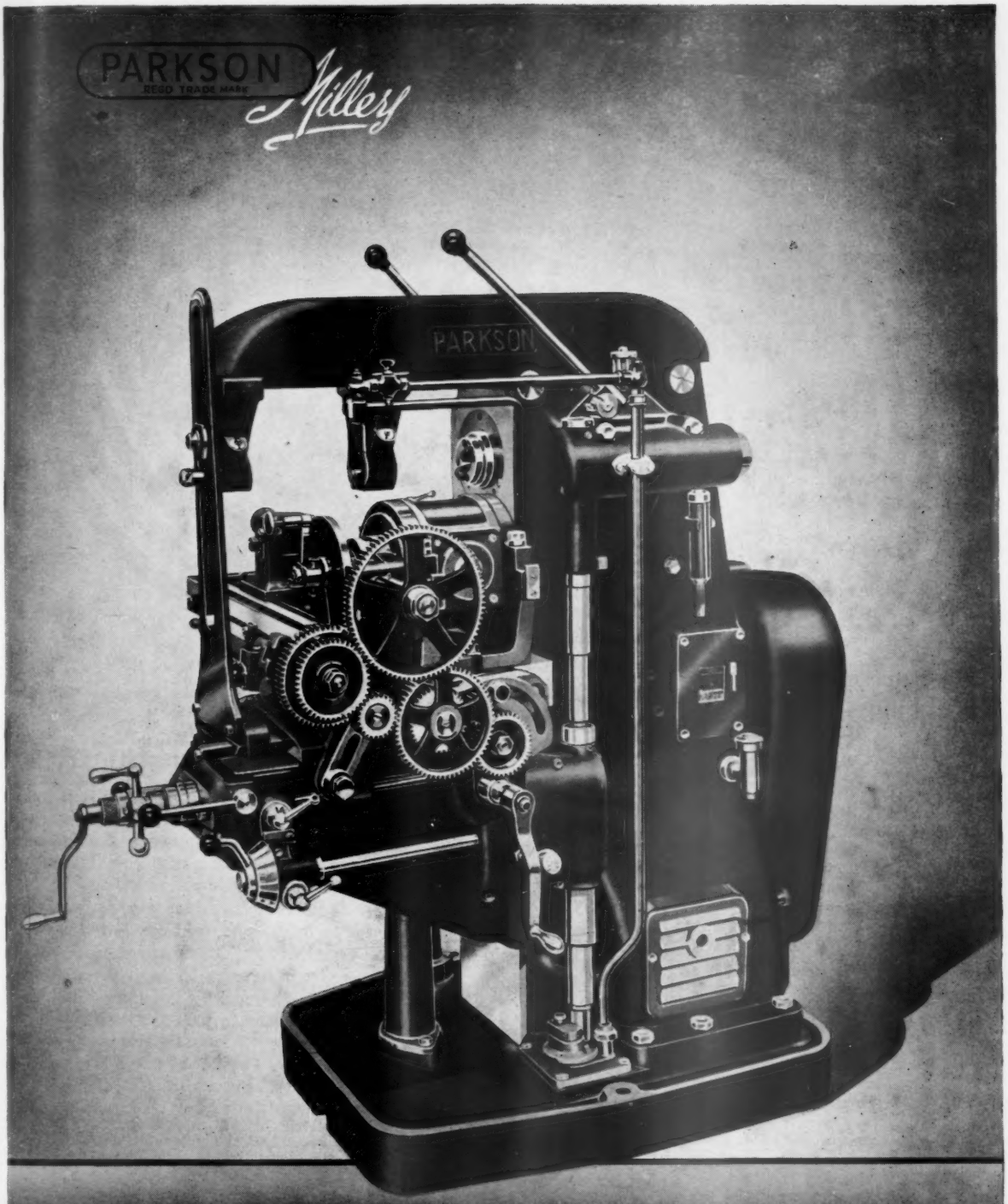

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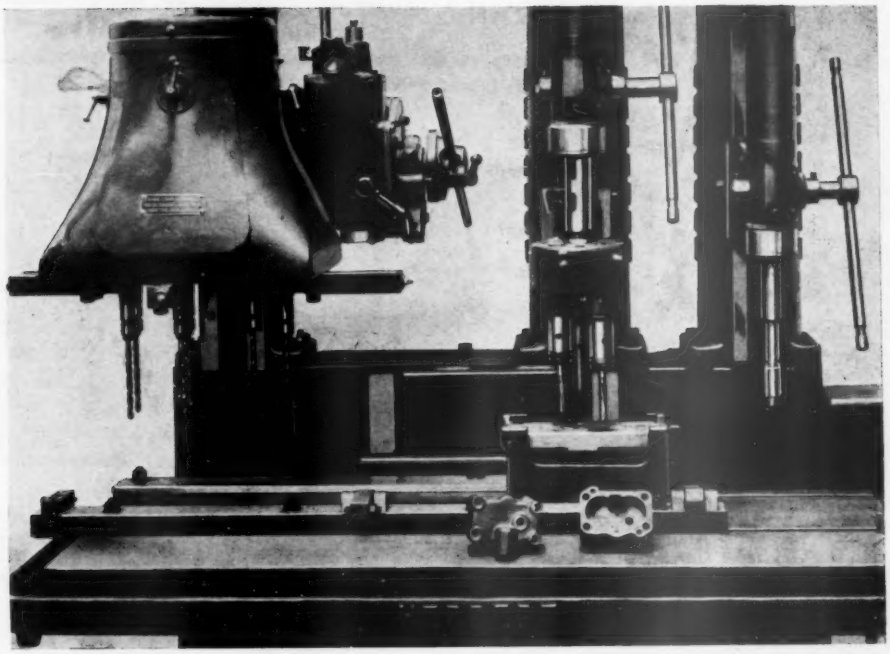

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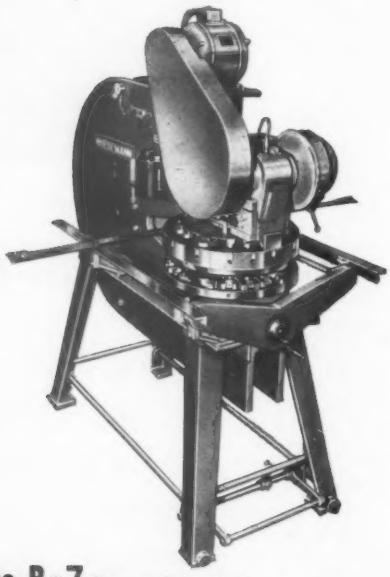
Type RA-41P Power-Operated
(Illustration shows Press fitted with pantograph type table)

Depth of throat	28″
Number of Stations	16 to 20
Maximum punch diameter	3⅛″

Type R-41P Power-Operated
(Illustration shows Press fitted with Standard Gauge Attachment)

Depth of throat	28″
Number of Stations	16 to 20
Maximum punch diameter ...	3⅛″



Type R-7 Power-Operated
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Capacity	160,000 lbs.
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Maximum punch size	6″ x 6″

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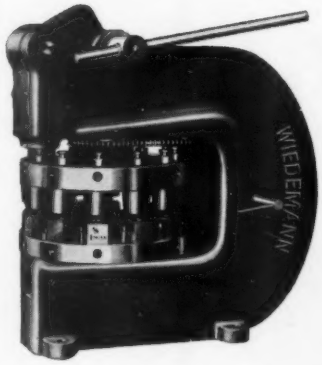
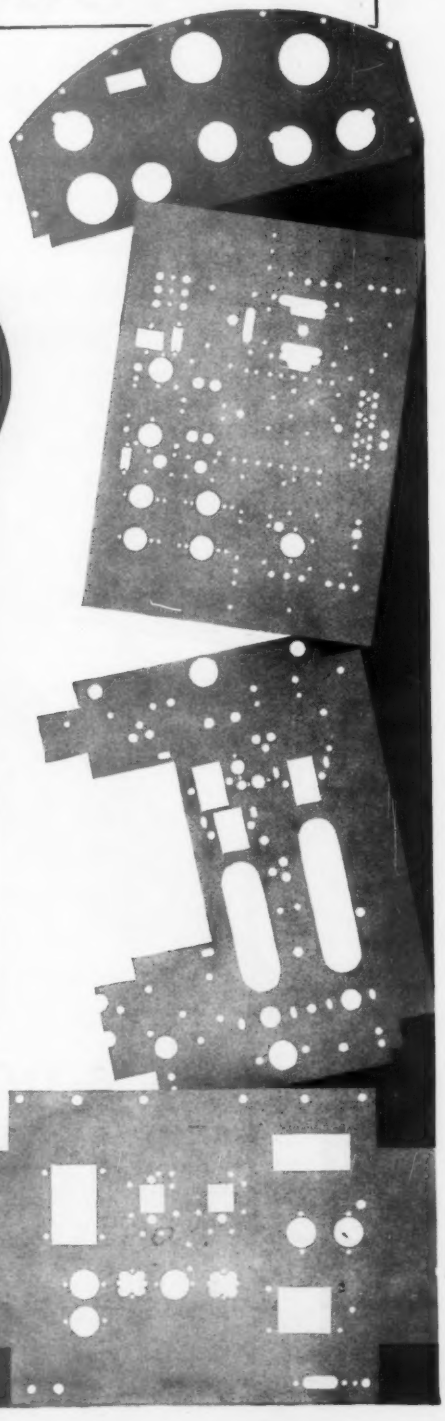


Type R-2 Hand-Operated for bench mounting

Depth of throat	12"
Number of Stations	12
Maximum punch diameter ...	2¼"

Type R-4 Hand-Operated with pedestal (Illustration shows gauge attachment)

Depth of throat	24"
Number of Stations ...	12
Maximum Punch diameter	2¼"



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TYPE		TYPE	
R.2 R.4	Up to 1/16" thick M.S. – 2.1/4" dia. Up to 1/8" thick M.S. – 1.1/4" dia. Up to 3/16" thick M.S. – 1/2" dia.	R.41P RA.41P	Up to 1/16" thick M.S. – 3.1/8" dia. Up to 1/8" thick M.S. – 2" dia. Up to 3/16" thick M.S. – 1.3/16" dia.
TYPE			
R.7	4" dia. hole in 1/4" thick Mild Steel 6" dia. or 6" x 6" square in 1/4" thick Mild Steel with sheared punches.		

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for C.E.J. manufactured thread rolls which fit M.S.E.-Fette Thread Rolling Heads

NEW PRICES PER SET OF ROLLS

Size	Price	Size	Price
0	£3 . 0 . 0	3	£7 . 10 . 0
1	£4 . 10 . 0	4	£15 . 0 . 0
2	£5 . 0 . 0	5 & 6	On Application

The above Rolls, produced by C. E. Johansson Ltd. from specially selected and heat treated steel to a very high degree of accuracy, ensure perfect thread forms and long tool life.
Thread Rolls reground at a fraction of the original cost.

C.E. JOHANSSON LTD.
PRECISION TOOLS AND INSTRUMENTS

SOUTHFIELDS ROAD, DUNSTABLE, BEDS. TEL: DUNSTABLE 422/3

DHB 1/2067

"I told him straight! . . ."

said the Factory Manager

"*I told the Guv'nor straight*," he said, "*— if you want this lot out on time, I want more up-to-date handling equipment!*"

We murmured admiration for his fearlessness . . . then we told him we were from Yale & Towne; we'd been called in by "the Guv'nor" to see how we could help.

"*Well, you can see for yourself the trouble*," he said, with a sweep of his hand. "*Hold-ups here — hold-ups there. We just can't keep the stuff moving.*"

We checked everything that was moved in, around and out of the factory. Our recommendations went to the Board.

A couple of months later we were back at the factory watching the early runs with the new equipment. Everyone was enthusiastic about the way things were going. They had every reason to be: production hold-ups had become a thing of the past.

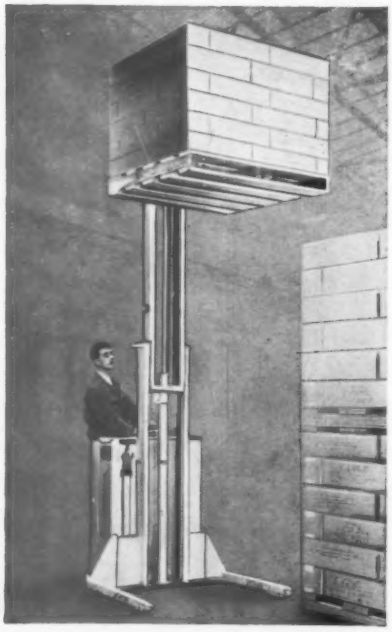
"*The way the Guv'nor's beaming, you'd think it was all his idea*," said the Factory Manager.

Why not pass your handling problems to us? Our Technical Representatives will call and advise you how Yale can solve your materials handling problems and help reduce production costs.

Here's a *new* answer to your "no-space" problem!

The new "Warehouser" range is the latest and most advanced driver-operated series of trucks now available . . . compact, more manœuvrable, fast and safe! The "Warehousers" give you all these outstanding advantages:—

- ★ Rounded rear end for right angle stacking in 5 and 6 foot aisles.
- ★ Lightweight for low floor loadings.
- ★ One hand operation for hoist, lower and drive.
- ★ "Dead man" control — applies brakes, cuts power.
- ★ Safe and easy driving position.
- ★ Fast handling speeds.
- ★ Straddle fork lift models available in 2,000 and 3,000 lbs. capacities, with standard lifts to 147". Pallet and low lift platform models up to 2 tons capacity.
- ★ Available with either lead-acid or nickel-alkaline batteries.
- ★ Low initial cost, low running cost, economical up-keep, long life.



The "Warehouser" Fork-Lift Straddle Truck.

MATERIALS HANDLING EQUIPMENT

MADE IN ENGLAND BY

YALE

REGISTERED TRADE MARK

THE YALE & TOWNE MANUFACTURING COMPANY

MATERIALS HANDLING DIVISION (DEPT. U5) · WEDNESFIELD · STAFFS · PHONE WILLENHALL 630

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AUTHORIZED DISTRIBUTORS:

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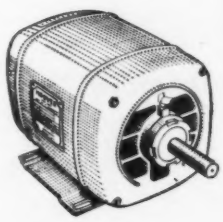

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FACE MILLS

for
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"GALTONA" carbide tipped inserted tooth face mills are showing their high production capabilities on a wide range of work at Salisbury Transmission Ltd., Birmingham. The illustration shows the facing of rear axle housings, a typical "GALTONA" job in this factory ; cut is 3/16" with a feed of 7" per minute. Material is malleable iron.

"GALTONA" O.K. inserted tooth cutters cover the whole range of milling operations with blades of high speed steel, solid "Stellite" or tipped with cemented carbide as desired.

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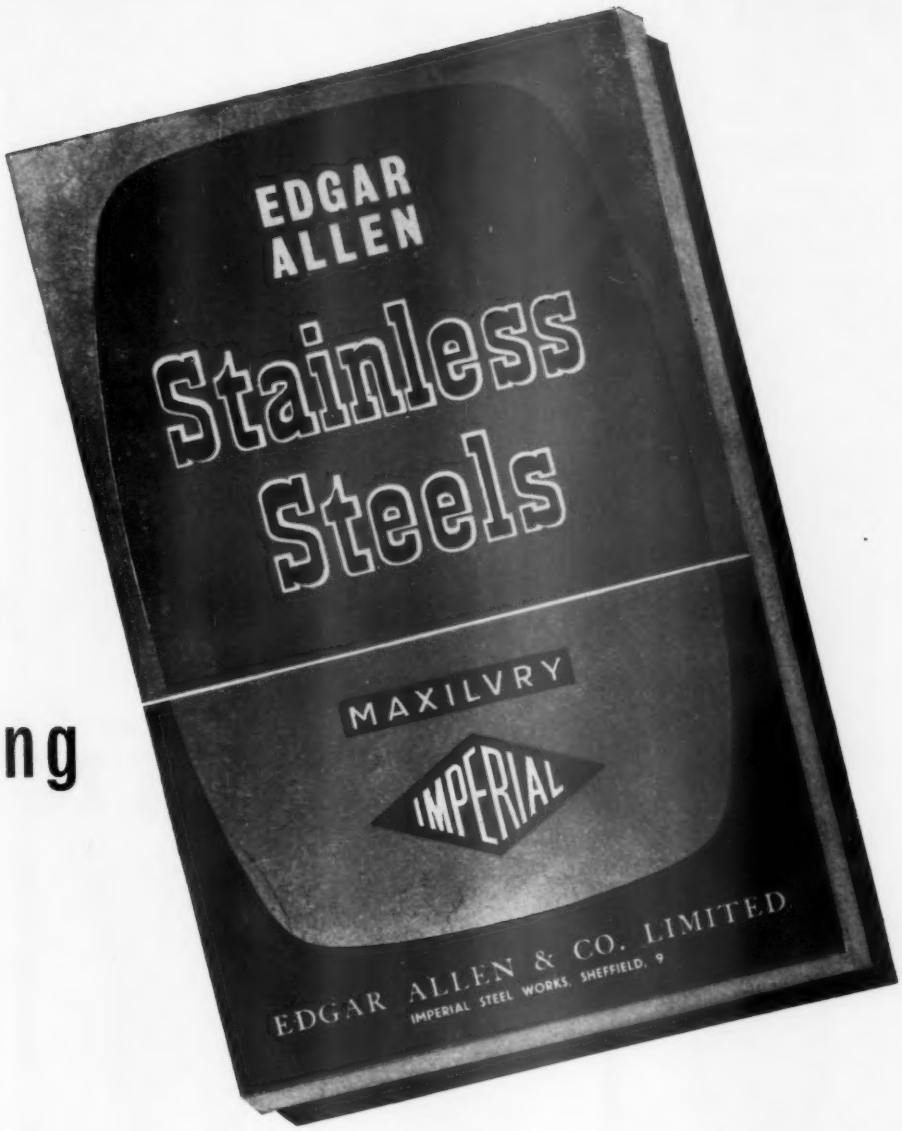

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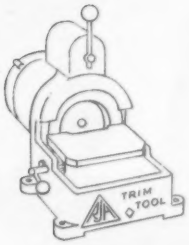

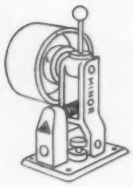

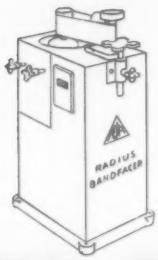

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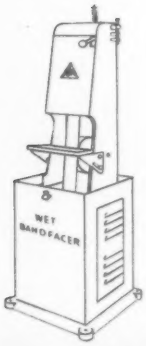

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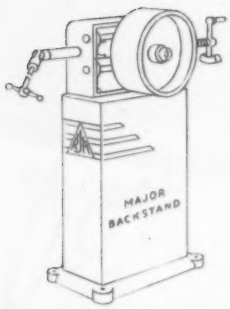

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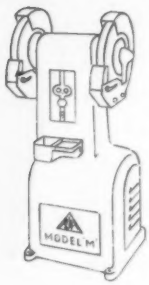

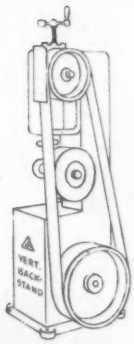

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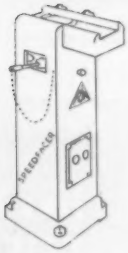

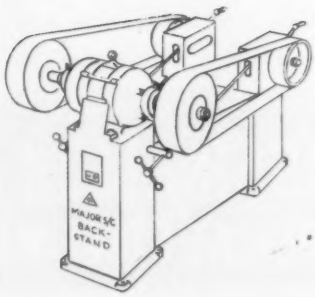

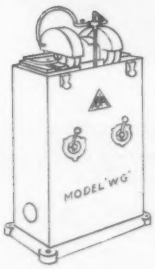

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There's no difficulty in keeping tools close to hand when you install "Steelpact" Tool-Stands. Manufactured from heavy gauge sheet steel, these sturdy units are available as plain stands with three trays or three trays and a steel locker.

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In Assembly Shops where maximum storage accommodation is required, "Steelpact" Work Benches are the ideal solution. Available in permanent and mobile forms, they provide that rigid work surface and ample storage space essential for efficient production.

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Safely locked away yet always visible, the contents of this "Steelpact" Locker can be checked at a glance without opening the door. The door and two sides are fitted with woven wire mesh, the top, back and bottom being of solid sheet steel.

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FAWCETT PRESTON

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Write for illustrated brochure describing:— Permanent, Semi-Portable and Mobile Work Benches, Tool Stands and Lockers. Inquiries also invited for Foremen's Desks and Testing Benches, Erection Trestles and other special or non-standard workshop furniture

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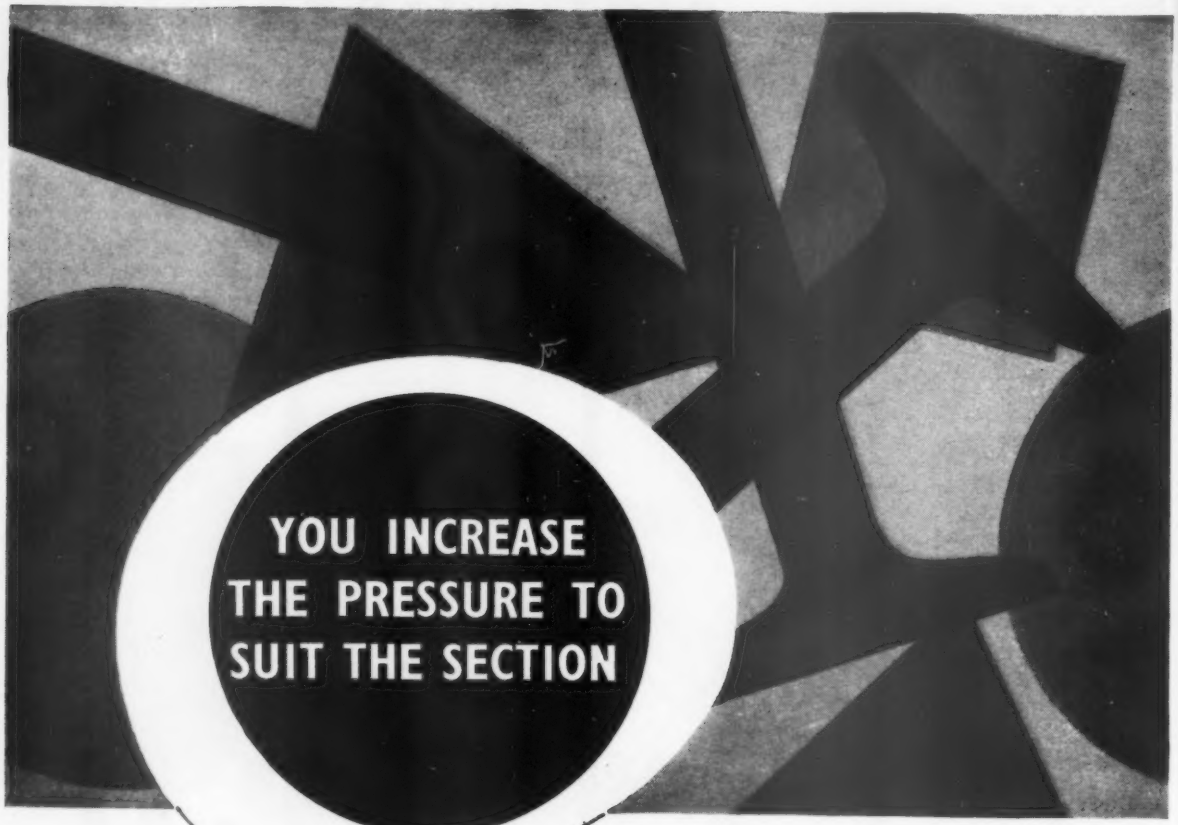

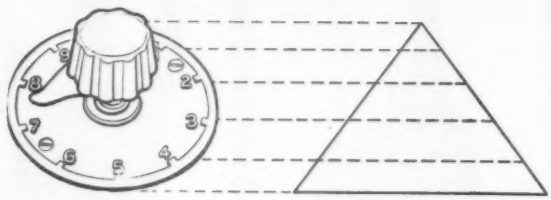

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SAWING MACHINE

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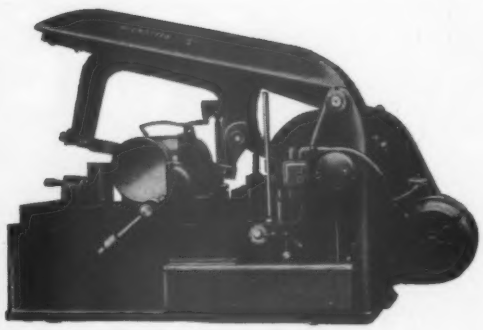

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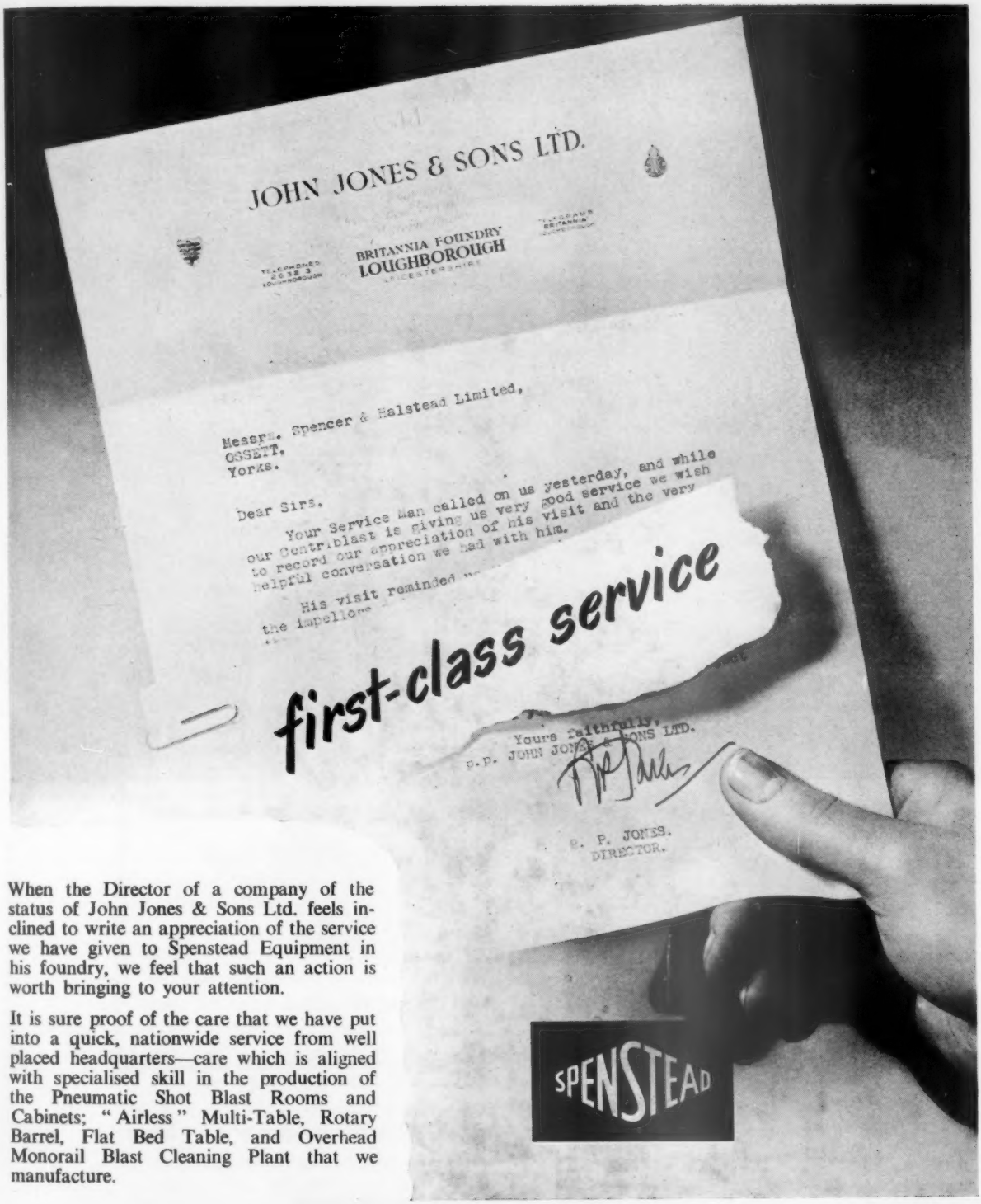

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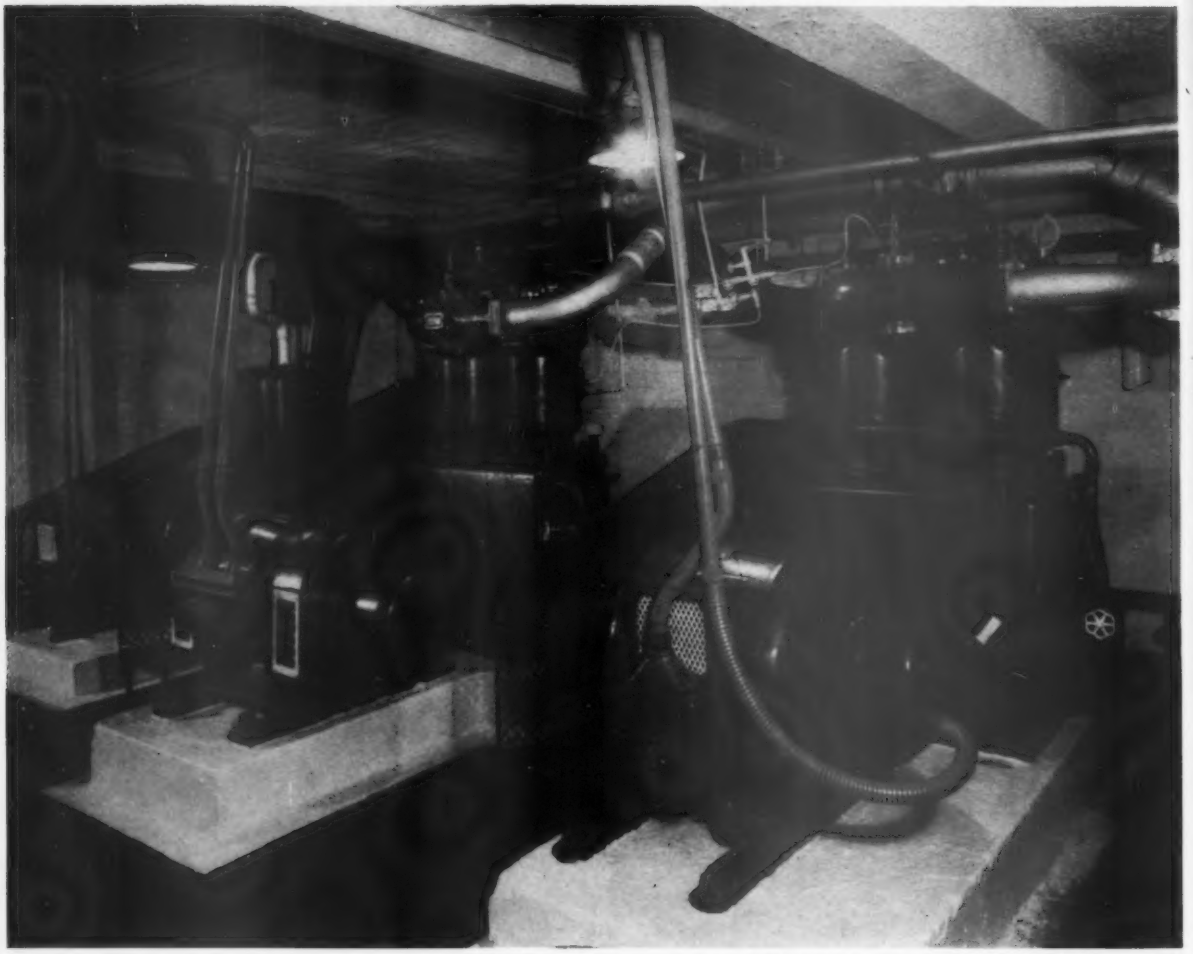

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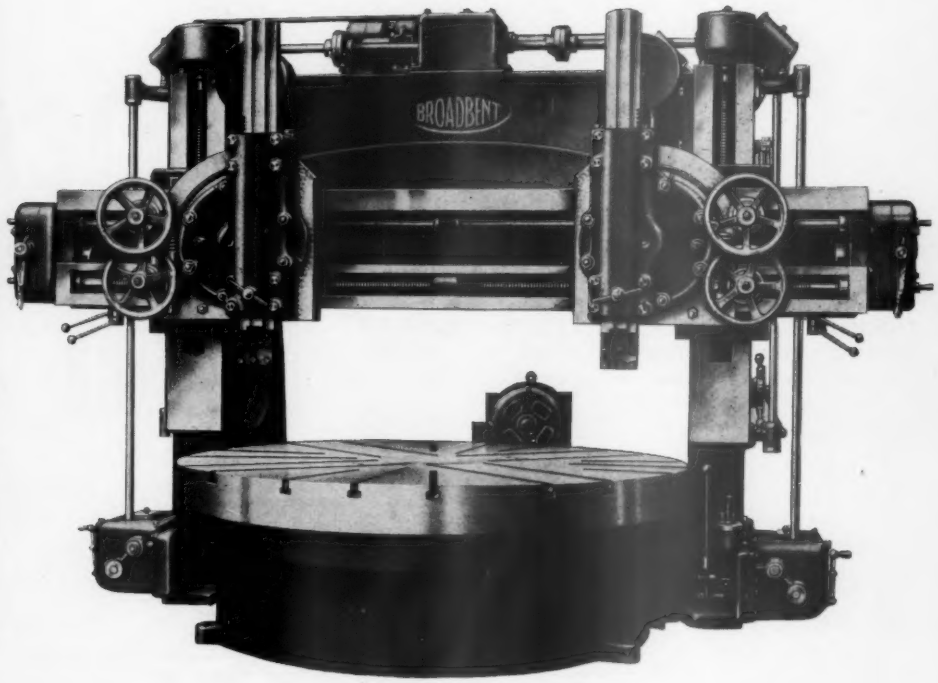

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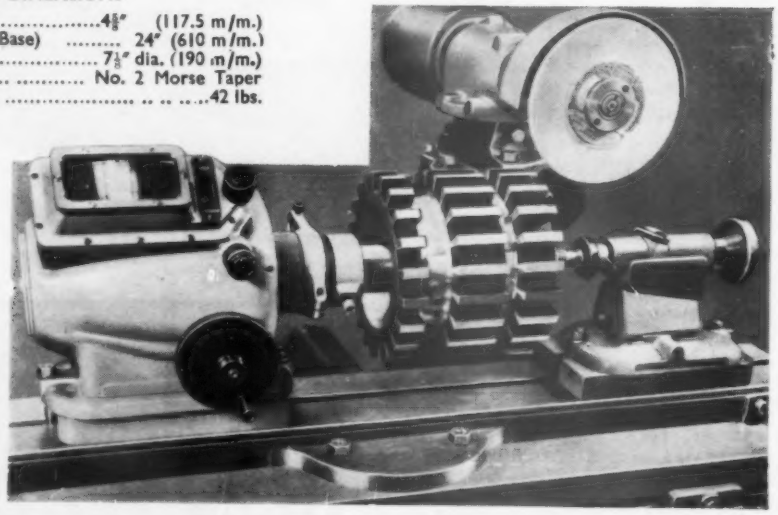
Size of centres	No. 2 Morse Taper
WEIGHT OF HEAD	42 lbs.



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WITH FIXED OR SWIVEL HEAD . .
giving a wide range of speeds
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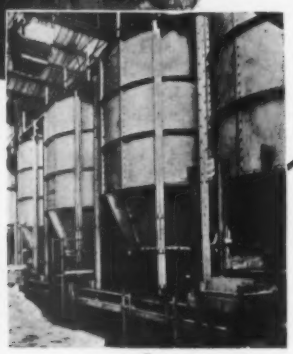
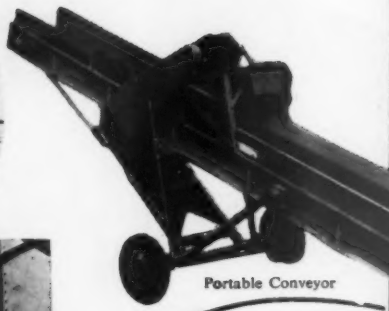


Sand Storage Hoppers

Pallet Conveyors



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Slat Conveyors

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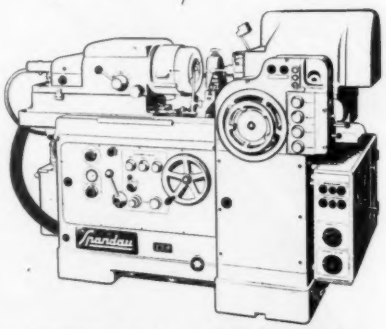
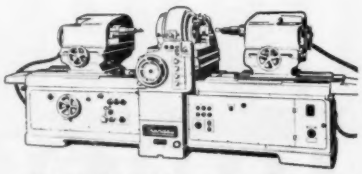


MODEL S.J. 11. Fully automatic. Available with sizing by positive gauging and/or by diamond control.



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An engineer may have a string of letters after his name but with constant development of new machines he can't know it all.

Until you've seen an actual demonstration of Spandau Fully Automatic Internal Grinding Machines you can't begin to appreciate the meaning of **really** high production. Ring Stanley Howard today for further details.

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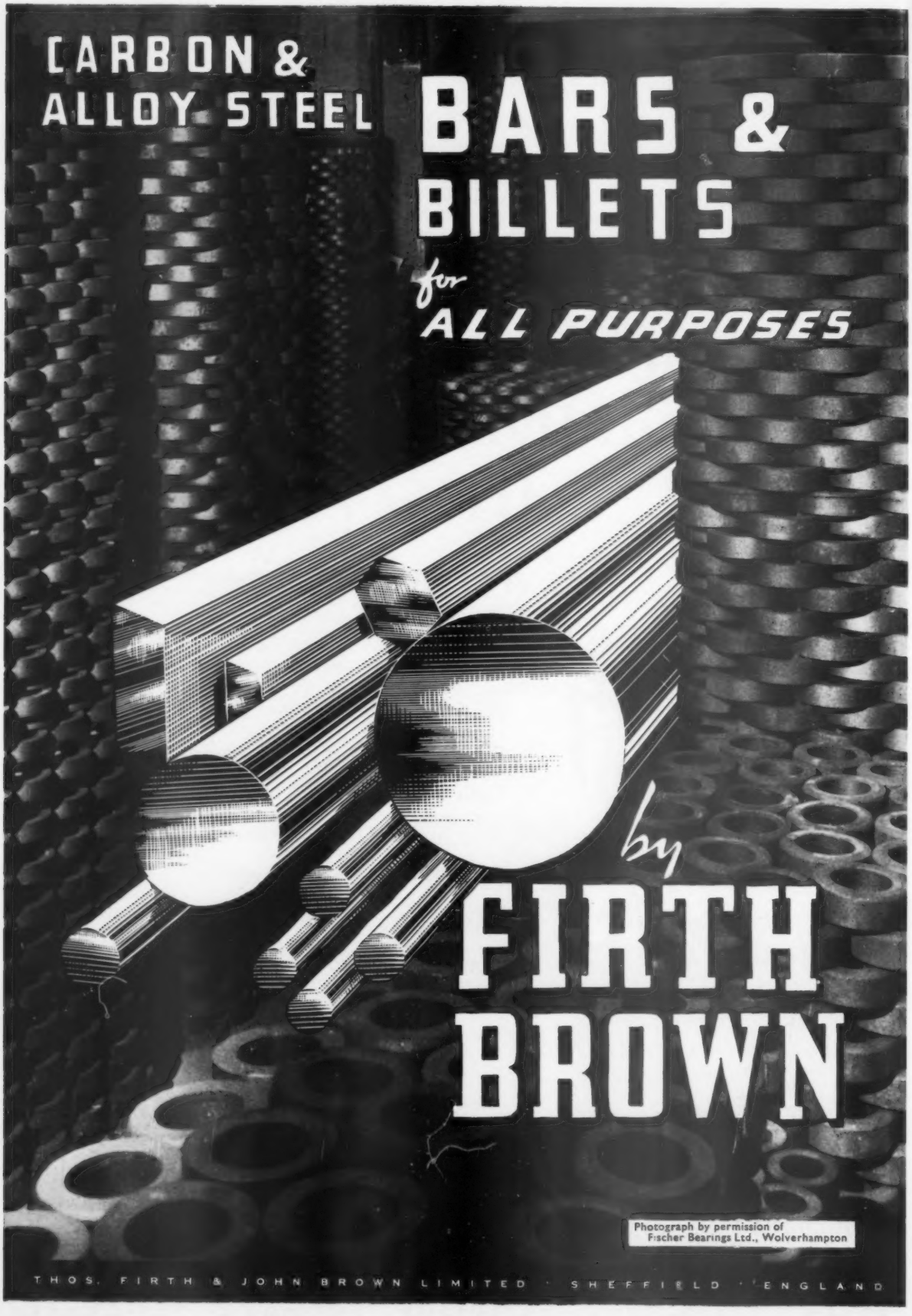
Spandau

Automatic Internal Grinding Machines


CARBON &
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BARS &
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THOS. FIRTH & JOHN BROWN LIMITED · SHEFFIELD · ENGLAND

ZBROJOVKA

Universal grinding machines

- ★ Infinitely variable table speed.
- ★ Robustly constructed with complete rigidity throughout ensuring a high degree of accuracy.
- ★ Easy in manipulation and set-up.
- ★ Ideal for all types and classes of grinding.

SPECIFICATIONS	MODELS BK3		MODELS BK5		
	500	750	750	1000	1500
Height of centres over table	5½"	5½"	6 1/16"	6 1/16"	6 1/16"
Max. distance between centres	20"	30"	30"	40"	60"
Grinding wheel (dia x hole x width)	13½"x2½"x5"	13½"x2½"x5"	19½"x3"x8"	19½"x3"x8"	19½"x3"x8"
R.p.m. of work	50—750	50—750	25—750	25—750	25—750
Table traverse per min.	4"—19' 8"	4"—19' 8"	4"—19' 8"	4"—19' 8"	4"—19' 8"
Table swivels by	6°	6°	6°	5°	5°
Work headstock swivels by	90°	90°	90°	90°	90°
Grinding headstock swivels by	45°	45°	30°	30°	30°

SOLE AGENTS

Selson MACHINE TOOLS

Early delivery from London stock

The Selson Machine Tool Co. Ltd

CUNARD WORKS, CHASE ROAD, NORTH ACTON, LONDON, N.W.10

Telephone: Elgar 4000 (10 lines) Telegrams: Selsomachi, London

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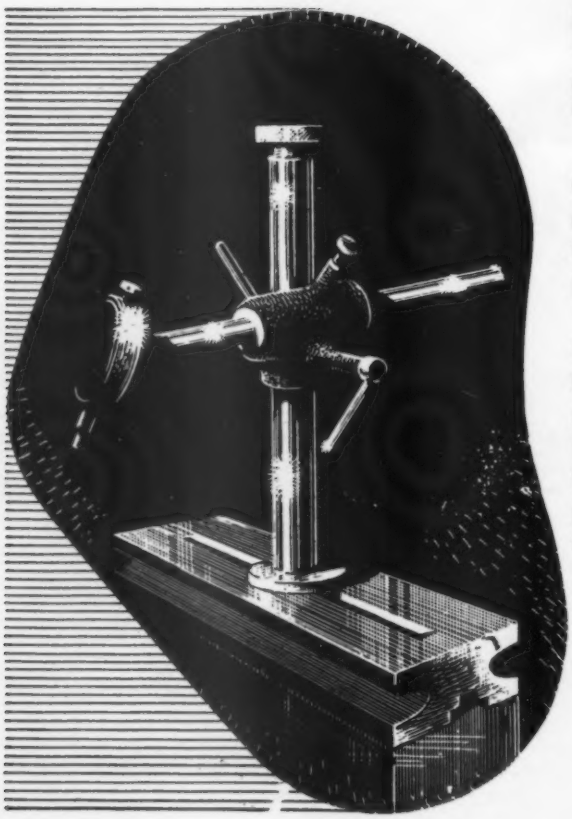

PRESS TOOLS · MOULDS AND SPECIAL PURPOSE MACHINES

Our commitments are heavy but we welcome an opportunity to study your requirements for inclusion in our production programme where possible.

Up-to-date shops specially laid out and equipped for making, on a production basis, every type of precision ground gauges; limit snap, form, calliper, taper and special purpose gauge, as well as jigs and fixtures of all kinds, press tools moulds and special purpose machines. Highest class workmanship and accuracy guaranteed.

Guaranteed
Precision
Accuracy

G.P.A.

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If a hen and a half . . .

The use of precision electrically timed stud welding on the production line for Morley washing machines has improved their appearance and efficiency by elimination of eighteen unsightly fixing screws previously visible on the enamelled top.

We do not claim to understand anything about the intricacies of egg production, but we do have a very sound knowledge of the mathematics of industrial production lines.

For instance, we know that if a man and a half welds a stud and a half in a minute and a half, there is something very serious amiss. We could soon show how one man, using our stud welding system, could weld 30 studs in less time than it takes to soft boil an egg, let alone lay one.

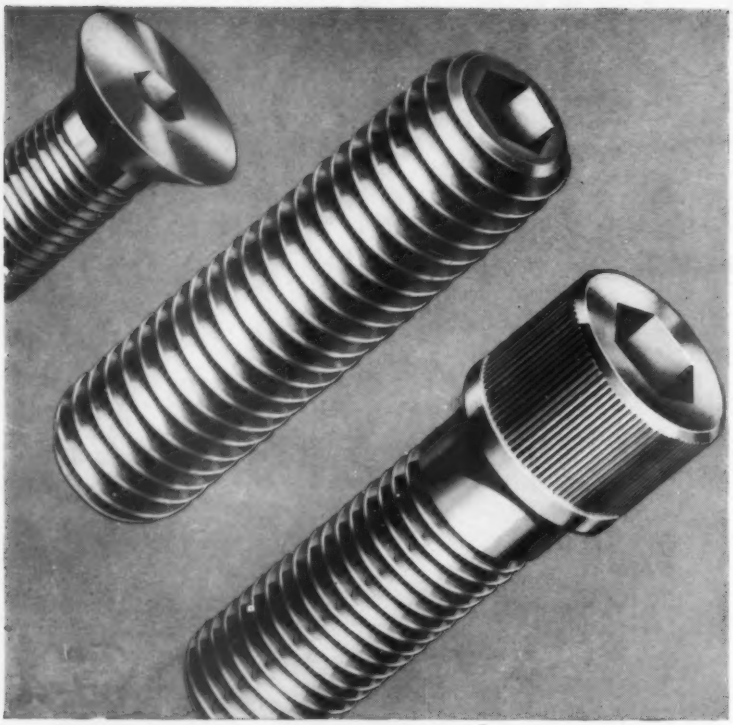
If you're laying on a plan to speed up production, call in

THE STUD WELDING ORGANISATION

Crompton Parkinson LIMITED

ELECTRICAL EQUIPMENT

1-3 BRIXTON ROAD, LONDON, S.W.9. TELEPHONE: RELIANCE 7676



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Unbrako Screws make a better job of it . . .

Where top-quality counts, Unbrako socket screws score every time. These tremendously tough, high-tensile socket screws, rigidly controlled at every stage of manufacture, are made to hairline-tolerance engineering standards, by the best equipped specialist screw organisation in Europe. Their superior strength usually means that when you specify Unbrako, you can use a smaller number of screws to take the same stress. They help to speed production too. There are Unbrako stockists all over the world.

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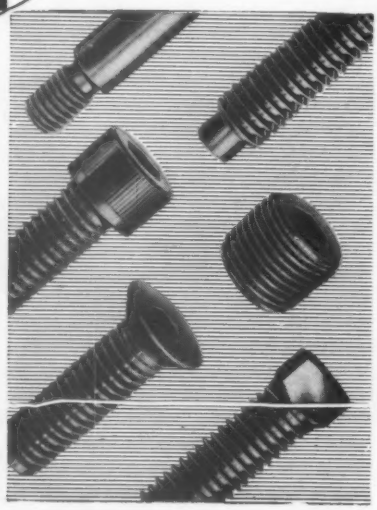
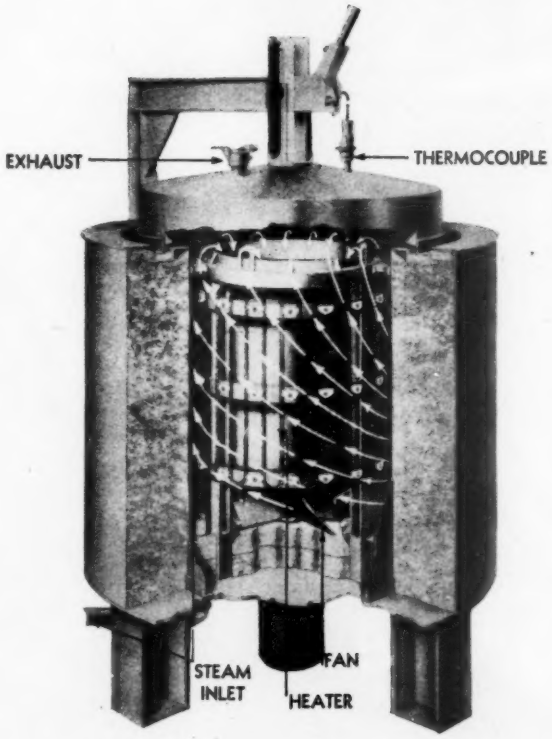


STEAM HOMO

tempering furnace



Remarkable results

At least 25% greater wear on cutting tools, cams, bearings, pistons, etc.

Clean scale free finish on ferrous and non-ferrous parts, eliminating after-cleaning.

Steam atmosphere tempering by the Steam Homo method turns out scale free ferrous and non-ferrous parts—they come out clean, with an attractive oxide film finish which often—particularly with copper and bronze—enables you to dispense with pickling and after-cleaning operations.

The effect of this oxide film is remarkable. High-Speed cutting tools hold their edge at least 25% longer and when cutting high-chrome or high carbon the ratio is greatly increased, and parts like cams, bearings and pistons wear in more sweetly and wear longer because the oxide film is porous and retains lubricants.

And if you put this compact furnace in your production line it will save you hours of handling. May we send you catalogue TD2-620(1).

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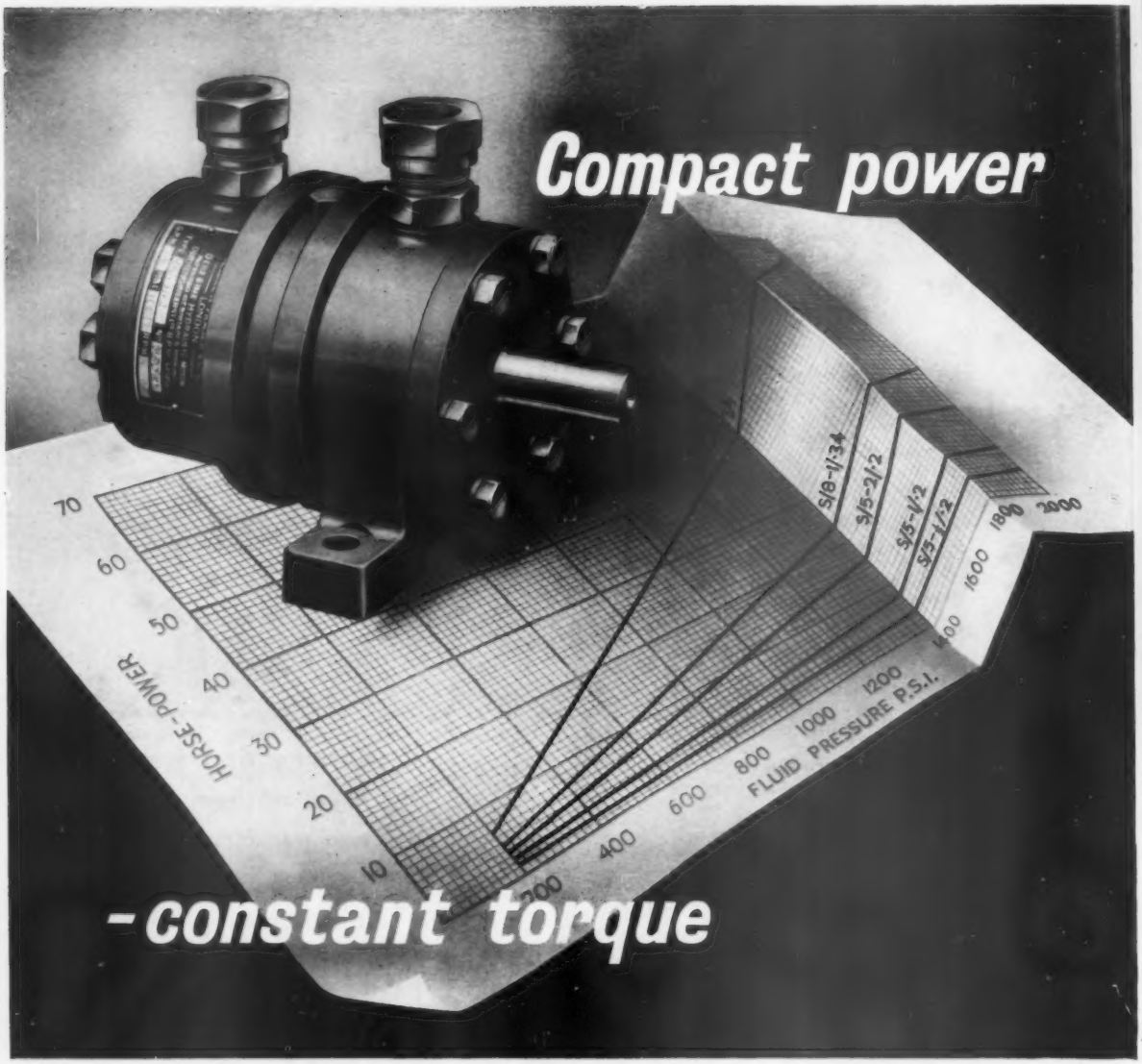
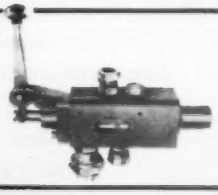
183 Broad Street Birmingham 15
'Phone: Midland 1453/4 *Telegrams: Flometer Birmingham*



Constant and full load starting torque is only one of the features of this outstanding hydraulic motor. It introduces high efficiency at low speeds and maintains it throughout the range, and provides exceptionally smooth transmission of power for a widely varied number of applications. Capable of rotation in both directions.

The smooth and vibrationless operation of the Motor is also a feature of the Deri-Sine Hydraulic Pump, a rotary displacement pump of high volumetric efficiency, which is essential to the power circuit.

An output of up to 4,000 lb./in. torque is available in a range of four basic sizes which incorporate variations in stator and rotor dimensions.



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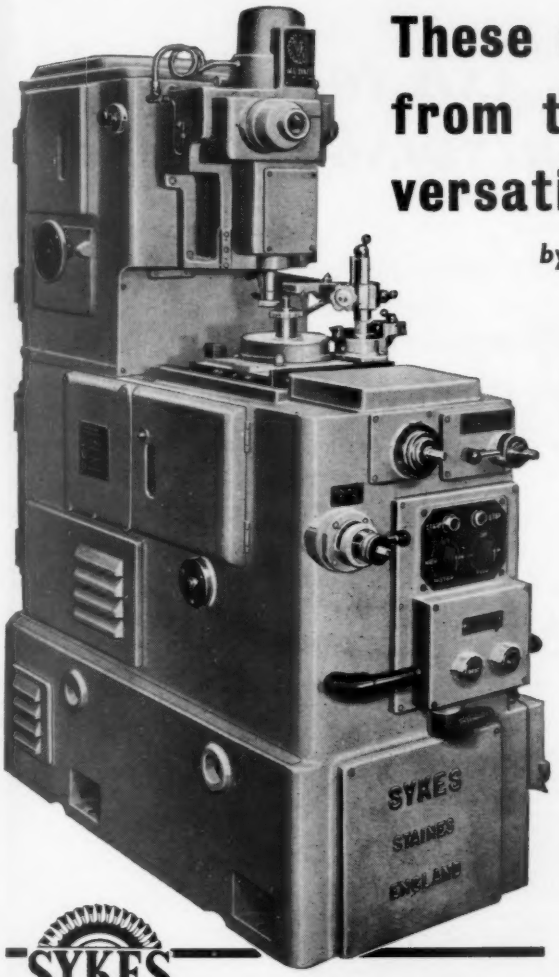

These are some extracts from the Report on the NEW versatile V.4 Gear Generator

by a well-known Engineering Journal ★

'The extreme flexibility of this type of Machine is not always fully realised . . .'

'Even more remarkable is the variety of intricate shapes that can be turned out . . .'

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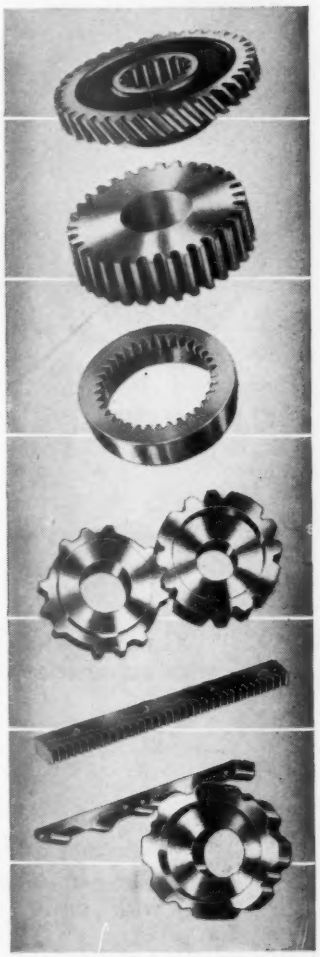
- EXTERNAL SPUR
- INTERNAL SPUR & HELICAL
- INTRICATE FORMS
- SPUR & HELICAL RACKS
- INTRICATE FORM FROM FLAT SECTION



External and internal spur and helical gears, splines and serrations can be produced at high output rates with great accuracy, and a Rack Cutting Attachment is available for generating spur and helical racks. Furthermore, intricate shapes that could otherwise only be produced in the tool room, can be formed exactly to size as a routine operation. Set up is simple — there are no cams to change, and the controls are grouped for ease of operation.

For gears up to 4½ in. dia. and ⅞ in. face, and racks up to 6 ins. long

Reasonably short delivery dates are offered

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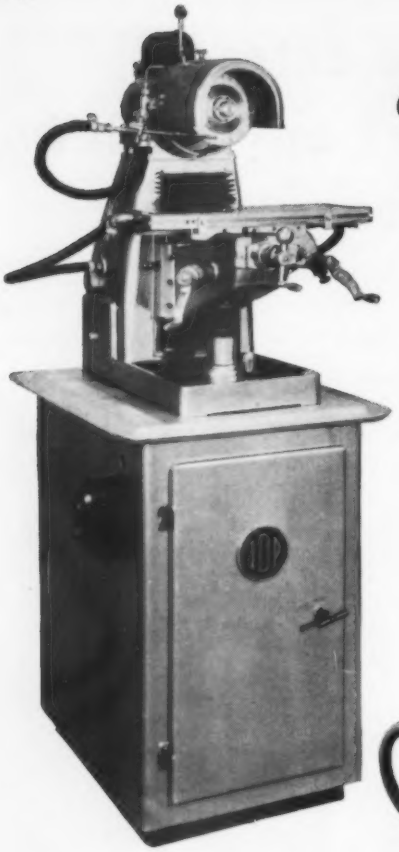

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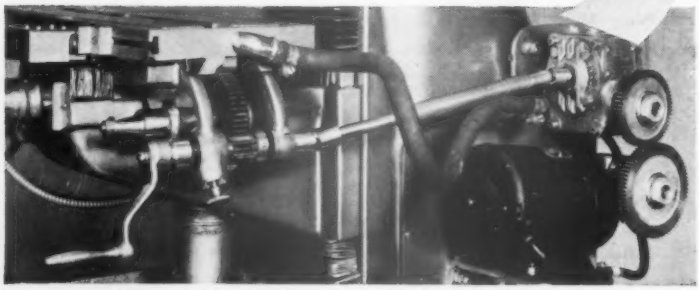
The G.F.3 was introduced originally to satisfy the demand for a small universal machine suitable for use with Neven Diamond Impregnated Tools for chipbreaker grinding and similar tool room work, and certain production operations.

The Mark II model has been developed on the same lines as the original Mark I, but with many improvements, and also a far higher degree of precision. As a result of numerous requests we have now added to our range the Mark IIa model with an automatic traverse; this retains the original simplicity of the Mark II with the addition of a sturdy and compact traversing unit.

G.F.3 MARK II

G.F.3 MARK IIa with automatic traverse



Close-up of assembly with cover removed

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We build a complete range of copper drawing machines for all the requirements of the Cable Maker. They are production tested machines, designed and built to give trouble-free HIGH PRODUCTION of GOOD QUALITY WIRE at LOW COST for a LONG TIME. They will not clean the wire, tin the wire, anneal the wire or enamel the wire but they will DRAW the wire and SPOOL it fast and faultlessly. We do not believe in any compromise which in the least affects their performance in these two vital functions.

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.750″ .500″	.300″ .128″	The PATHFINDER with 30″ dia. blocks non slip drawing under back tension with shaving between first and second dies; in coils or in big spools.
.375″ .250″	.160″ .040″	The TANDEM ROD MACHINES-submerged drums and dies; 7, 9 or 11 dies, finishing .072″ or .064″ at 5000 feet per minute.
.144″ .104″	.072″ .020″	TYPE 13H HEAVY INTERMEDIATE: really fast – .104″ to .056″ at 6000 feet per minute on spools.
.128″ .064″	.048″ .008″	TYPE MS.4 – 13, 15 or 17 dies – submerged cones and dies for high quality.
.072″ .040″	.020″ .005″	TYPE 21.F2 – PS.4.AC.: A high speed fine wire machine with the patent permanent magnet spooler.
.036″ .008″	.008″ .002″	TYPE 16.F1 – PS.4.AC. The fine wire machine of the range; like the type F2 above, it gives high speed and faultless spooling.
.006″ .002″	.003″ .001″	TYPE 10.F PS.2.AC. Superfine; will draw and spool wires below .001″ if required.

May we expand on the brief descriptions above? Please write and ask for more details. . . .

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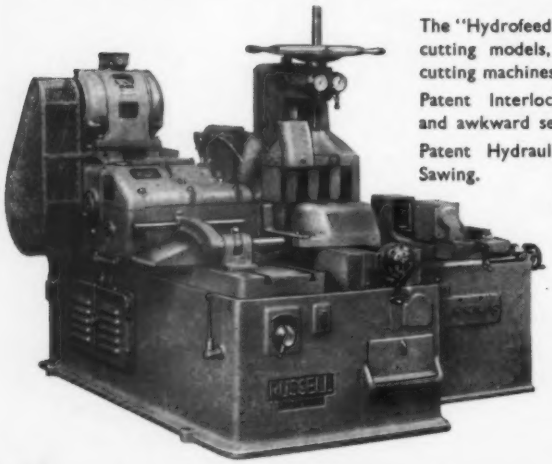

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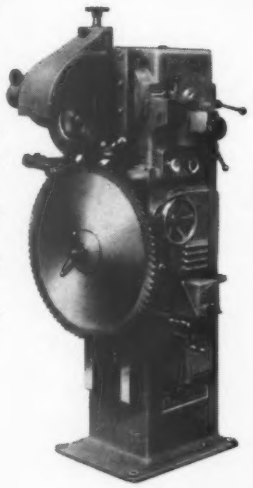

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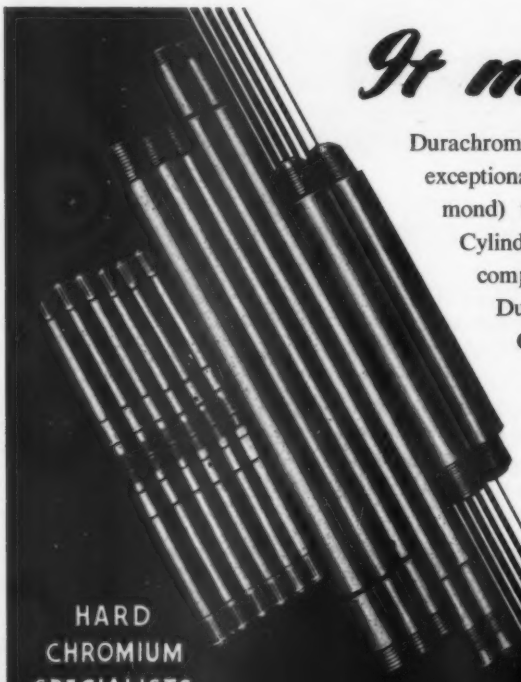

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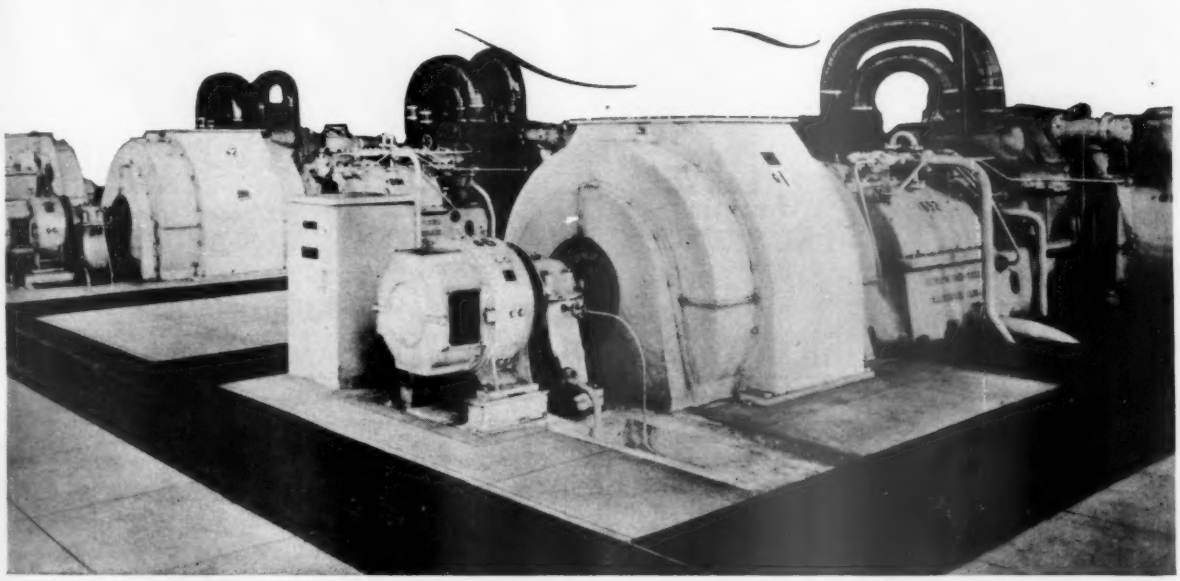

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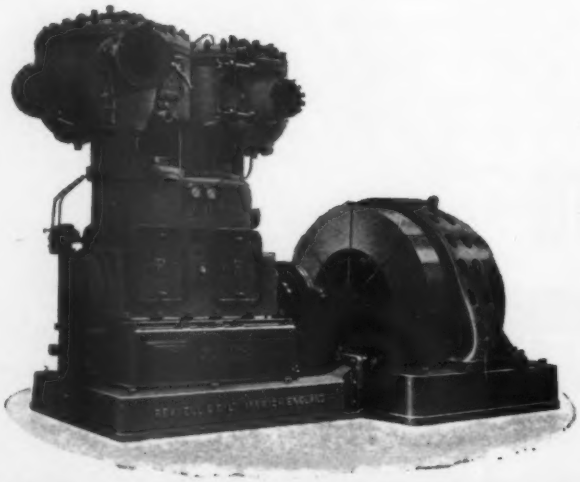

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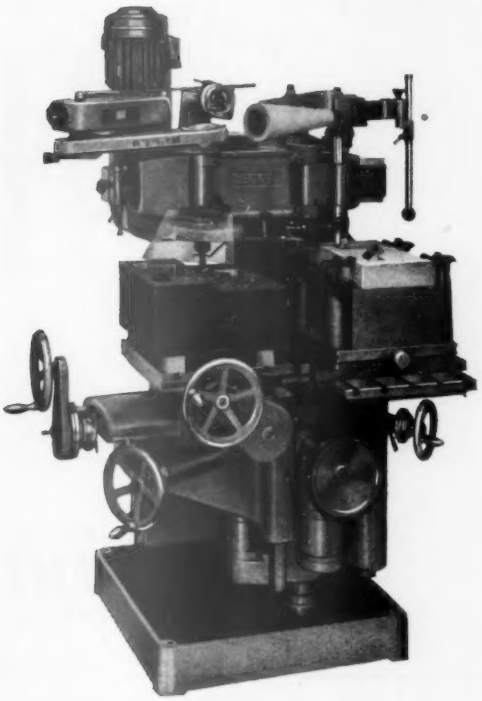

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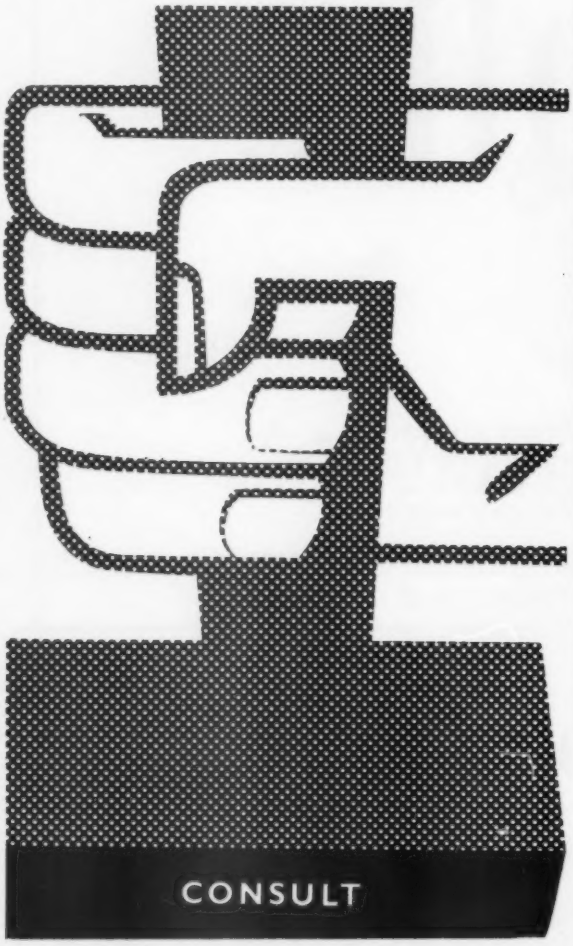

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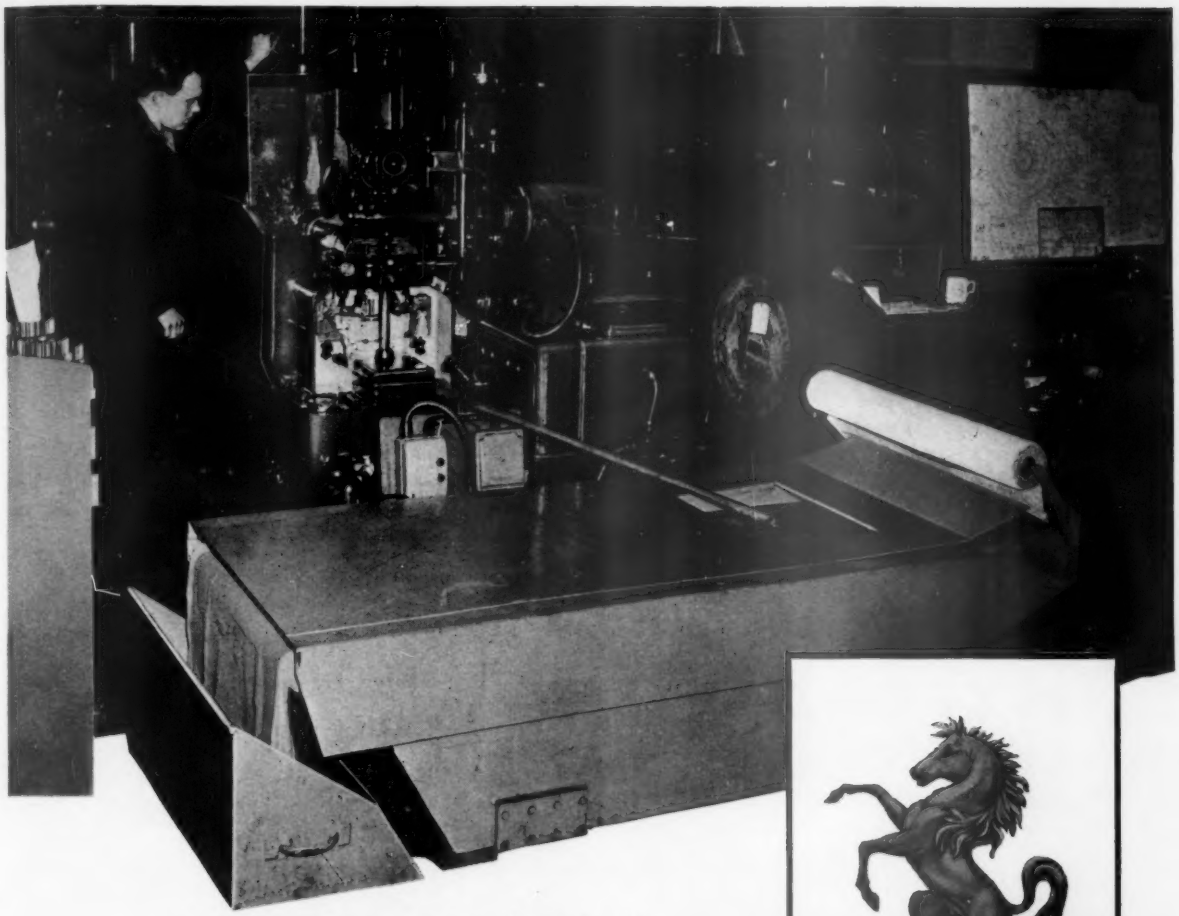

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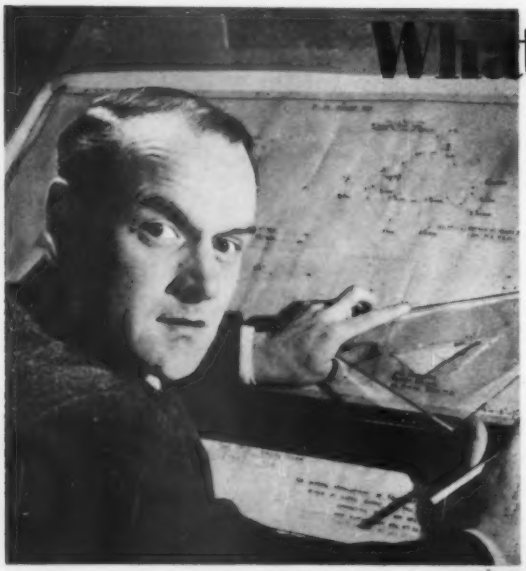

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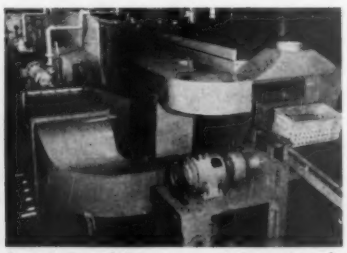
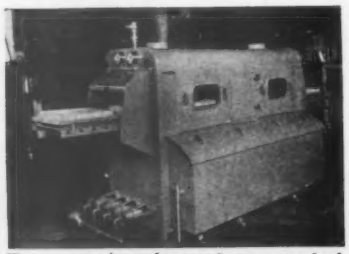


A power driven conveyor system is employed with this cleaning machine for ball bearings.



Trays carrying the work are pushed through on a roller conveyor by hand in this cleaning installation.

Whilst offering a very wide variety of standard cleaning equipment, it is BRATBY policy, wherever possible to design the machine to meet the particular cleaning problem. Careful study of each individual problem ensures maximum efficiency and economy of the plant in operation. The illustrations show but a few of the specific types of Cleaning Machines designed by BRATBY for individual needs.

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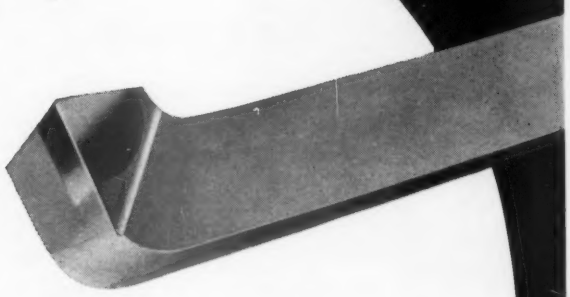

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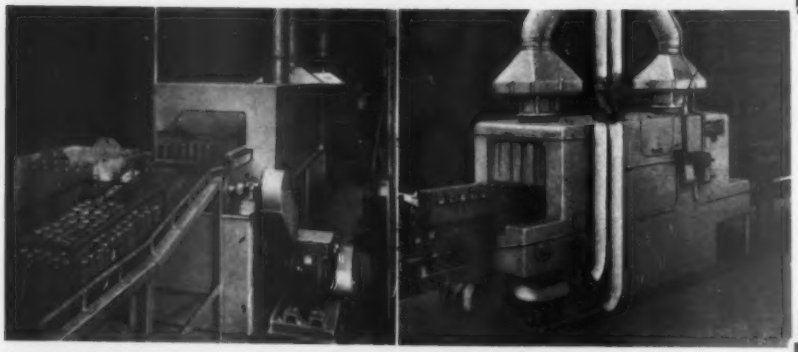

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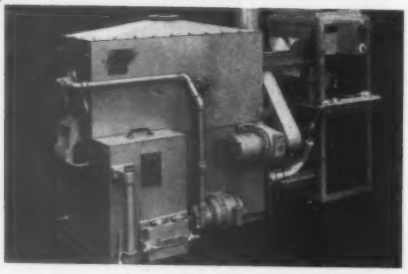

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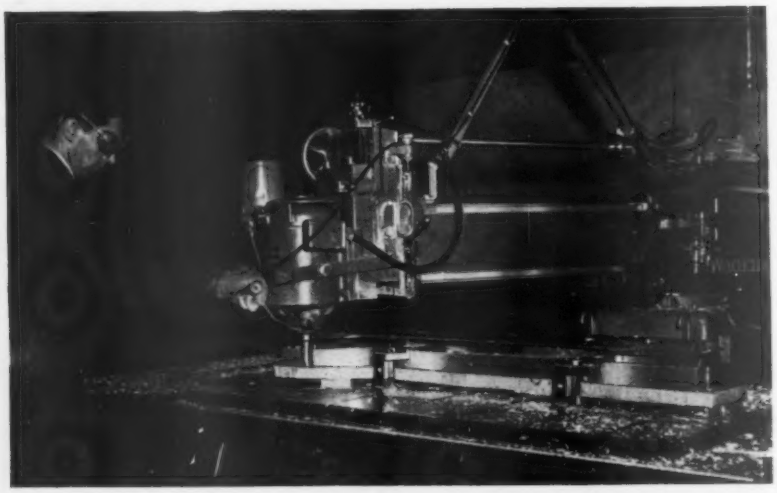

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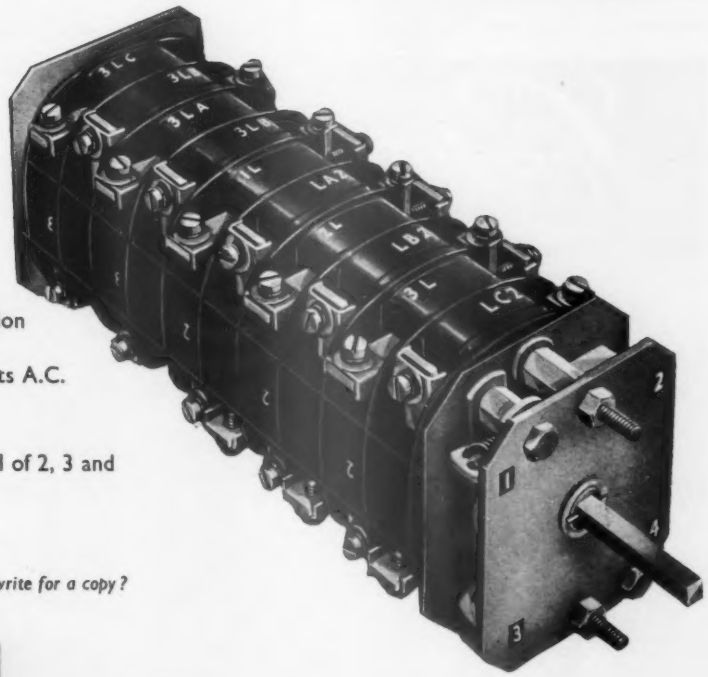

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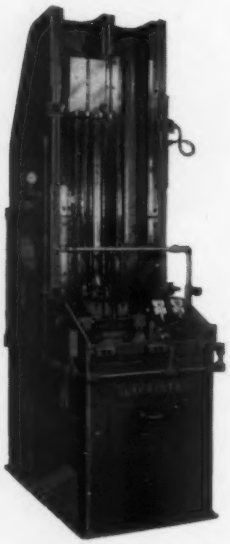

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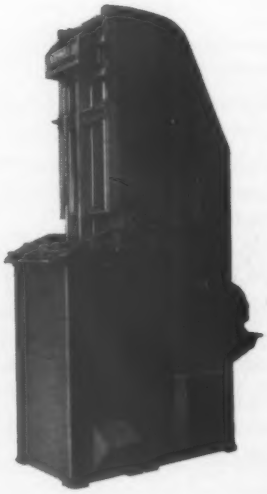

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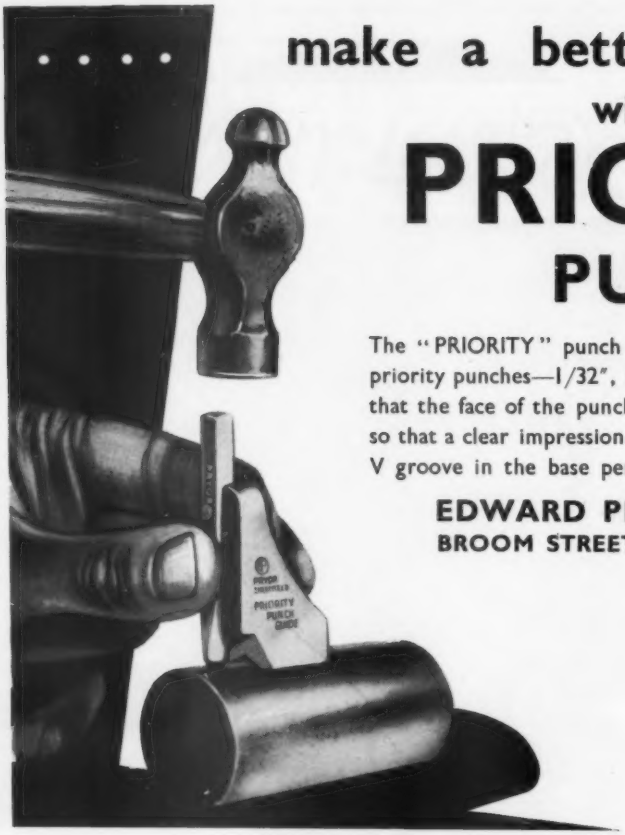

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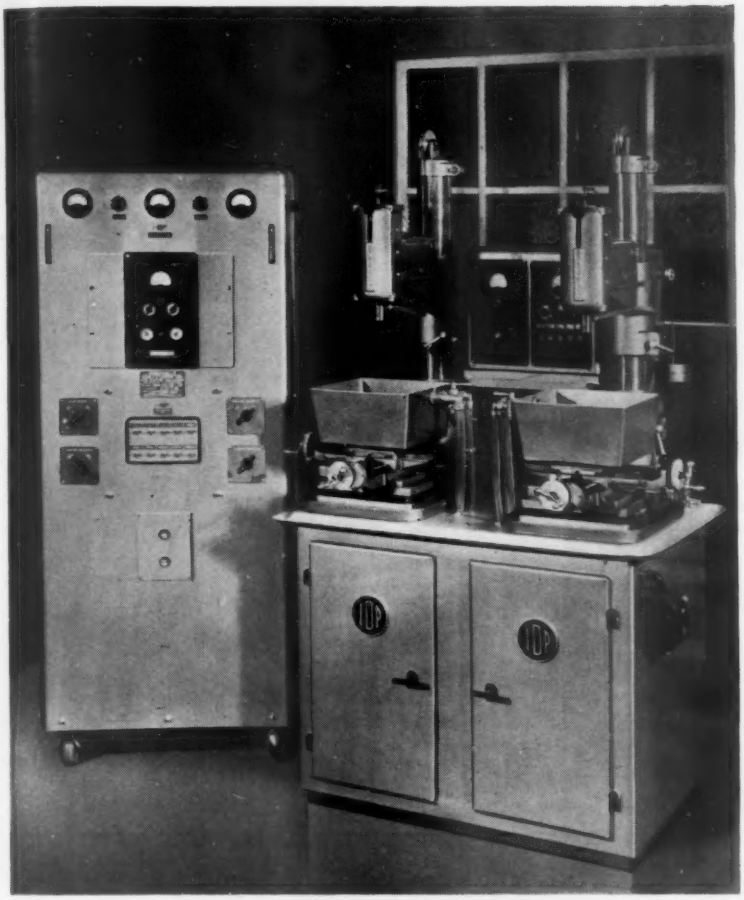

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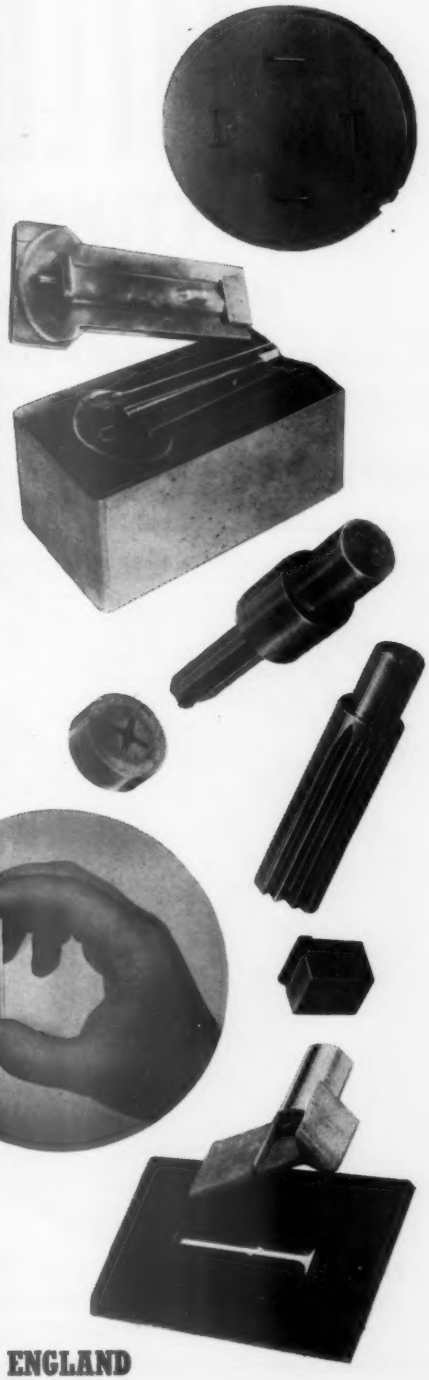

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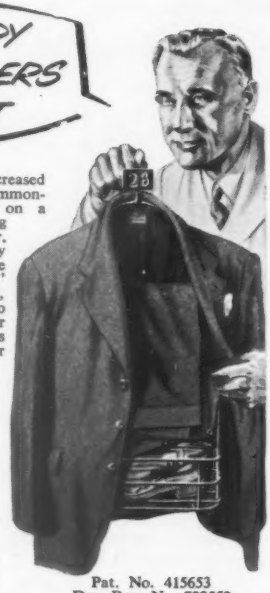

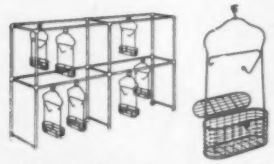

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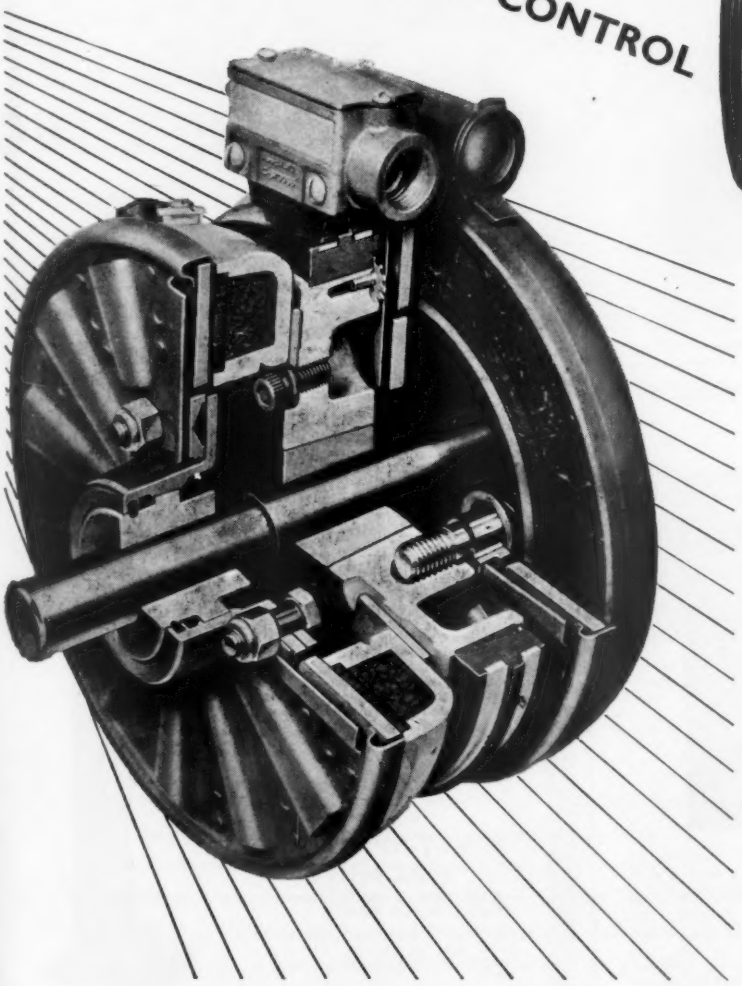

WARNER

Electric BRAKES & CLUTCHES

are world renowned for accurate, shockless and instantaneous control of rotating drives.

These compact, mechanically simple units will help you to increase the output from your machines by simplifying control, and reducing lost time when starting and stopping. Remote push button operation now possible reduces operator fatigue and facilitates fully automatic operation when desired.

Warner Industrial Electric Brakes and Clutches give instant operation—adjustable torque—constant automatic adjustment for wear—effective heat dissipation—with compact installation, low power requirements and WITHOUT ENDTHRUST.

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ST. HELEN'S AUCKLAND, CO. DURHAM

Phone: West Auckland 317 (4 lines) Grams: Solenoid, West Auckland

TIB 10

We're consumers of our own steel bars!

Our experience in working and machining our own steels in our own engineering shops is an important factor in producing high quality bars.

Engineers prefer

KIRKSTALL
bright steel bars

Carbon and alloy also fully heat treated to engineering specifications

KIRKSTALL FORGE ENGINEERING LTD. LEEDS 5 Tel: Horsforth 2821

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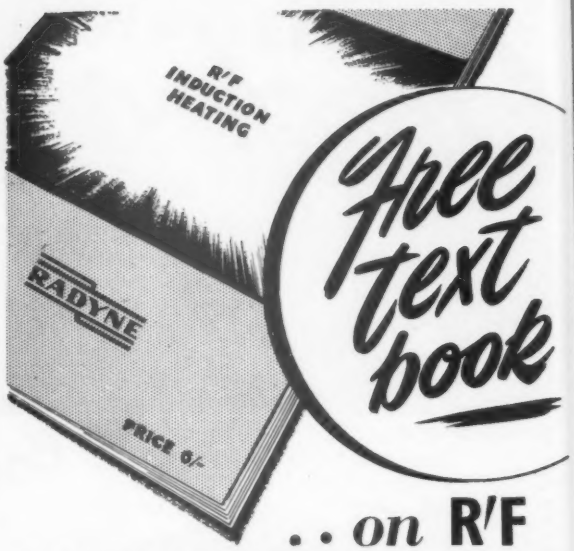


Free text book

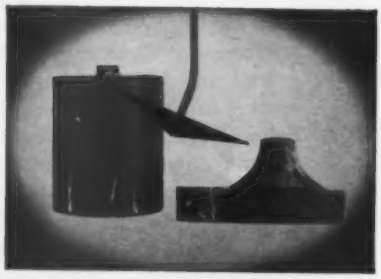
. . on R/F INDUCTION HEATING

. . . a new publication of outstanding importance to all interested in brazing or heat treating.

WRITE ON YOUR LETTER HEADING FOR YOUR FREE COPY OF PUBLICATION IH. 401, ADDITIONAL COPIES 6/- EACH

radio heaters ltd., wokingham, berks.

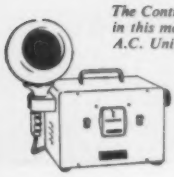
Cracks SHOW LIKE THIS



A really positive method of non-destructive testing of metal, plastic or ceramic components is to be found in the fluorescent test using the Hanovia Model 16 Lamp in conjunction with suitable inks. Both magnetic and non-magnetic processes are available and details will gladly be sent on request.

Hanovia are the world's leading manufacturers of u'tra-violet equipment for all purposes, including many industrial processes and testing measures. Their technical staff are always ready to discuss manufacturers' problems where the use of ultra violet radiation may be able to offer a solution.

The Control Unit with its handle and bracket forms the mounting in this model. The D.C. Unit weighs 10¾ lbs. complete : and the A.C. Unit 18 lbs.

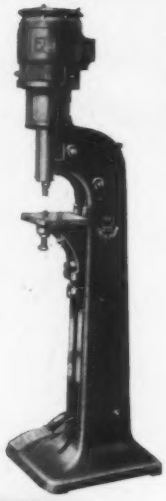


HANOVIA
Fluorescent Crack Detection
HANOVIA · SLOUGH · BUCKS

If it can be Riveted . . .

HERE IS HOW YOU CAN SPEED UP THE JOB—AND CUT COSTS.

If you produce riveted assemblies where speed in operation and a neat appearance are as important as a properly formed rivet head—it will pay you to investigate T.T. Rivet Spinning machines. The wide range of machines available are suitable for cold rivetting in all sizes up to ½ in. diam. mild steel. It includes bench and floor models, air and foot operated and " Duplex " spinners for heading both ends of pins for hinges, chains, etc. Write for full details and latest literature.



RIVET SPINNING MACHINE

R.S.S. VMD. ⅛ in. Capacity. Foot operated model.

Ask for a demonstration. Full technical advisory service available. Samples of articles would be appreciated.

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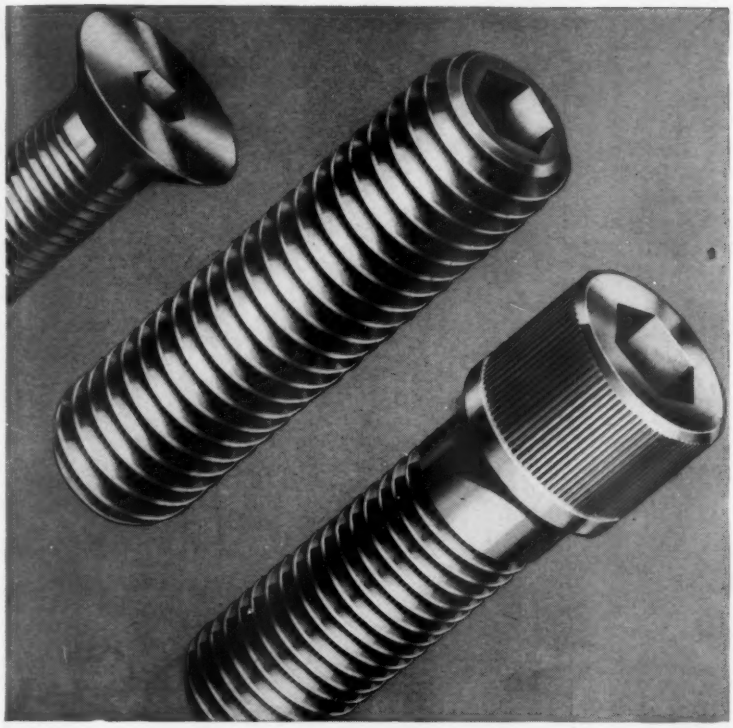
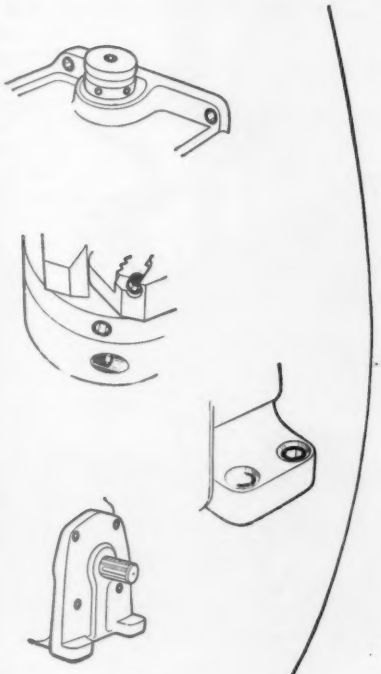
MACHINE TOOLS LTD
63-68, PRINCIP ST., BIRMINGHAM, 4

Telephone : Aston Cross 2244.





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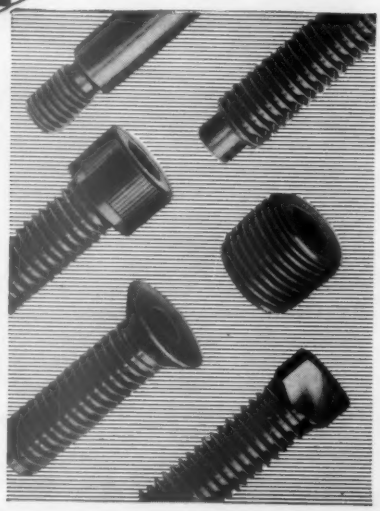
UNBRAKO

Unbrako Screws make a better job of it . . .

Where top-quality counts, Unbrako socket screws score every time. These tremendously tough, high-tensile socket screws, rigidly controlled at every stage of manufacture, are made to hairline-tolerance engineering standards, by the best equipped specialist screw organisation in Europe. Their superior strength usually means that when you specify Unbrako, you can use a smaller number of screws to take the same stress. They help to speed production too. There are Unbrako stockists all over the world.

UNBRAKO SOCKET SCREW CO. LTD. · COVENTRY



and £4,000 damages

A press operator whose earnings are retarded by slow guard operation is a menace to himself and to you. He is tempted to expose himself to danger, and may involve you in heavy damages. Fortunately, the 'Fastrip' Synchronised Guard ensures the highest standard of safety without impeding production. Send for full details today.

BIF 2-13 May
CASTLE BROMWICH BIRMINGHAM
SEE OUR EXHIBIT

Stand D 606

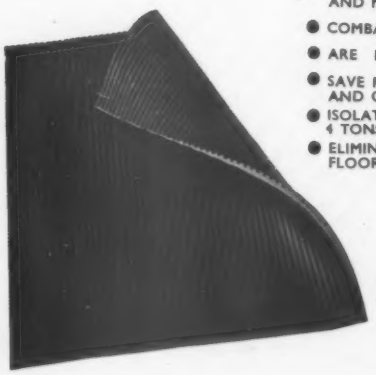
J. P. UDAL Ltd
INTERLOCK WORKS, COURT ROAD, BIRMINGHAM, 12.
Telephone: CALthorpe 3114

Udal PRESS GUARDS

VULCASCOT ANTI-VIBRATION PADS
OIL RESISTING

Improve Production!

- CHECK VIBRATION SHOCK AND NOISE
- COMBAT NERVOUS STRAIN
- ARE EASY TO INSTALL
- SAVE MAINTENANCE TIME AND COST
- ISOLATE LOADS UP TO 4 TONS PER SQ. FT.
- ELIMINATE CUMBERSOME FLOOR FIXINGS



Standard Size
18 × 18" × ⅞"

Manufactured by:

VULCASCOT (Great Britain) LTD.
87-89, ABBEY ROAD, LONDON, N.W.8.
PHONE: MAIDA VALE 7374 & 7375. 'GRAMS: VULCASCOT MAIDA VALE LONDON

-this badly worn spur gear

replaced promptly and accurately by this

We supply Spurs, Spirals, Bevels Worms and Wheels complete or from customers blanks.
Your enquiries will receive prompt and reliable attention.

we specialise in breakdowns

RELIANCE GEAR & ENGINEERING CO. (SALFORD) LTD.
DICKINSON STREET · SPRINGFIELD LANE · SALFORD 3
Phone: BLAckfriars 0164 & 1715 Grams: MOTOGEARS

PREVENT SABOTAGE by Dust and Damp!

Dust and damp can cause serious breakdowns- particularly in equipment which cannot be brushed out. The answer lies in "Secomak" Portable Electric Blowers- the most powerful obtainable and equally useful as suction cleaners. Model 7 weighs only 10lb. but delivers air at 340 ft. per second. Model 70 weighs 15 lb. and delivers air at 425 ft. per second.

Both models will blow air at temperatures up to 600° F. with the "Secomak" Heater Attachment for drying damp insulation etc.

Write for data sheet 101/P.E.

Secomak REGD

PORTABLE
ELECTRIC BLOWERS
AND SUCTION TOOLS

We also make lightweight stationary units for high velocity suction and blowing suitable for many industrial processes. See data sheets 104, 132, 130 P.E. for full particulars.

SERVICE ELECTRIC CO. LTD.
HONEYPOT LANE · STANMORE · MIDDX. EDGware 5566-9

Lloyds link casting and machining...

saves you time, transport and money, and guarantees a perfect job

One of the great features of Lloyds foundry is that, in addition to producing the castings, it is superbly equipped to machine them. The advantages are obvious—two major operations are centralised, valuable time is saved, and the customer is spared the expense of transporting rough castings to independent machine shops.

Castings of up to 25 tons come within the machining capacity of Lloyds. Typical of the Company's impressive machining resources is the Graffenstaden Horizontal Boring Machine. This machine is a recent acquisition to the Machine Shop. It is of the most modern design, and some idea of its capacity can be gauged from the fact that it can bore to a diameter of 2′ 7½″, and possesses a maximum spindle stroke of 7′ 10½″. Among other interesting machines are the 16′ Craven Vertical Borer, and a 20′ Craven Planer both of which are continually employed in machining heavy castings. *Send for your copy of Lloyds Craftsmen in Steel. Post Free.*

Lloyds new machine shop gives you extra foundry service

F. H. LLOYD & CO. LTD. · P.O. BOX 5 · JAMES BRIDGE STEELWORKS · WEDNESBURY · STAFFS · PHONE: DARLASTON 225

A Print for Industry Ltd. advertisement

INDEX TO ADVERTISEMENTS

	Page
Adams Bros. & Burnley, Ltd.	—
Accles & Pollock, Ltd.	—
Adapta-Charts, Ltd.	LXXXII
Adcock & Shipley, Ltd.	V
Allen, Edgar & Co., Ltd.	XXXV
Alumilite & Alzak, Ltd.	LXXXII
Archdale, James & Co., Ltd.	XLIII
Arrow Electric Switches, Ltd.	—
Asquith, William, Ltd.	XX
Automatic Coil Winder & Electrical Equipment Co., Ltd., The	—
Automation, Ltd.	—
B.I.P. Chemicals, Ltd.	LXXXI
Barber & Colman, Ltd.	—
Bawn, W. B. & Co., Ltd.	—
Bedford, John, & Sons, Ltd.	XXX
Birlec, Ltd.	—
Birmingham Aluminium Casting (1930) Co., Ltd.	—
Black & Decker, Ltd.	XVII
Bratby & Hinchliffe, Ltd.	LXVIII
Bray, Accessories, Ltd.	—
British Aero Components, Ltd.	—
British Die Casting & Engineering Co., Ltd.	LXXXV
British Electrical Development Association, The	XXVI
British Tabulating Machine Co., Ltd.	LXIII
British Thomson-Houston, Co., Ltd.	—
Broadbent, Henry, Ltd.	XLI
Brookhirst Switchgear, Ltd.	LXXV
Broom & Wade, Ltd.	XL
Brown, David, Corporation (Sales) Ltd., The	—
B.S.A. Tools, Ltd.	—
Burton Griffiths & Co., Ltd.	LXI
Butterley Co., Ltd., The	—
Catmur Machine Tool Corporation, Ltd.	LXX
Churchill, Charles & Co., Ltd.	—
Churchill Machine Tool Co., Ltd.	—
Cincinnati Milling Machines, Ltd.	III
Climax Rock Drill & Eng. Works Ltd.	XVI
Cohen, George, Sons & Co., Ltd.	—
Cossor, A. C., Ltd.	—
Coventry Climax Engines Ltd.	*Outside Back Cover*
Coventry Gauge & Tool Co., Ltd.	—
Cow, P. B., Ltd.	LXXIV
Croda, Ltd.	LXXVIII
Crofts (Engineers), Ltd.	—
Crompton Parkinson, Ltd.	XLIX
Dawson Bros., Ltd.	LXX
Dean Smith & Grace, Ltd.	VIII
Dowding & Doll, Ltd.	XXVIII, XXIX
Drummond-Asquith (Sales), Ltd.	XXII
Drummond Bros., Ltd.	XXI
Duckham, Alex. & Co., Ltd.	—
Durachrome, Ltd.	LVIII
Dyson & Co., Enfield (1919), Ltd.	VI
Edibrac, Ltd.	—
Electro-Chemical Eng. Co., Ltd.	—
Elgar Machine Tool Co., Ltd.	LXXIII
English Electric Co., Ltd., The	IX
Exors of James Mills, Ltd.	X
Fawcett, Preston & Co., Ltd.	XXXVII
Fescol, Ltd.	—
Firth Brown Tools, Ltd.	IV
Firth, Thos., & Brown, John, Ltd.	XLVI
Fisher & Ludlow, Ltd.	—
Flame Hardeners, Ltd.	—
Fletcher Miller, Ltd.	LXXX
Fox, Samuel & Co., Ltd.	—
Fractional H.P. Motors, Ltd.	—
Fraser, Andrew & Co., Ltd.	LII
Gledhill-Brook Time Recorders, Ltd.	LXXVI
G.P.A. Tools & Gauges, Ltd.	XLVIII
Guest, Keen & Nettlefolds (Midlands), Ltd.	—
Guylee, Frank, & Son, Ltd.	LX
Hanovia, Ltd.	LXXXIV
Harrison, T. S., & Sons, Ltd.	—
Harris Tools, John, Ltd.	—
Herbert, Alfred, Ltd.	XXVII
Hilger & Watts, Ltd.	—
Holman Bros., Ltd.	—
Hoover, Ltd.	XXXIII
Horden, Mason & Edwards, Ltd.	XV
Horstmann Gear Co., Ltd., The	LXXX
Howard, Stanley, Ltd.	XLV
Humphris & Sons, Ltd.	—
Hymatic Engineering Co., Ltd., The	XXIII
Imperial Smelting Corporation (Sales), Ltd.	—
Impregnated Diamond Products, Ltd.	LIV
Integra, Leeds & Northrup, Ltd.	LI
Intermit, Ltd.	LXXII
Jessop, Wm. & Sons, Ltd.	LXIX
Johansson, C. E., Ltd.	XXXI
Jones, E. H. (Machine Tools), Ltd.	—
Jones, Sidney G., Ltd.	—
King, Geo. W., Ltd.	—
Kirkstall Forge Engineering, Ltd.	LXXXIV
Lang, John, & Sons, Ltd.	—
Lang Pneumatic, Ltd.	—
Lansing Bagnall, Ltd.	—
Lapointe Machine Tool Co., Ltd., The	LXXVI
Ley's Malleable Castings Co., Ltd.	—
Leytonstone Jig & Tool Co., Ltd.	—
Lloyd, F. H. & Co., Ltd.	LXXXVII
Lloyd, Richard, Ltd.	XXXIV
London Oil Refining Co., Ltd., The	—
Lund, John, Ltd.	LXVII
Machine Shop Equipment, Ltd	—
Machinery Publishing Co., Ltd.	—
Magnesium Elektron, Ltd.	XIV
Manganese Bronze & Brass Co., Ltd.	XII
Marbaix, Gaston E., Ltd.	—
Marsh Bros., & Co., Ltd.	—
Marshall-Richards Machine Co., Ltd.	LVII
McGraw-Hill Publishing Co., Ltd.	—
McKechnie Bros., Ltd.	—
Metal Industries Group	XXXVII, LXXV
Metropolitan-Vickers Electrical Co., Ltd.	LIX
Midland Iron Co., Ltd., The	LVI
Mollart Engineering Co., Ltd.	LXXIV
Monks & Crane, Ltd.	VII
Morane Plastic Co., Ltd.	—
Morris, B. O., Ltd.	XIII
Myford Engineering Co., Ltd.	LXVI
Neill, James, & Co. (Sheffield) Ltd.	—
Newall, A. P. & Co., Ltd.	LXII
Newall Group Sales, Ltd.	XIX, LXV
Newall Group Sales, (Tolimit Gauges) Ltd.	—
Park Gate Iron & Steel Co., Ltd.	*Inside Back Cover*
Parkinson, J., & Son (Shipley), Ltd.	XXV
Paterson Hughes Engineering Co., Ltd.	XLIV
Pilot Works, Ltd.	—
Powers Samas Accounting Machines (Sales), Ltd.	LV
Precision Grinding, Ltd.	XLII
Press Equipment, Ltd.	—
Prestware, Ltd.	LXVIII
Pryor, Edward, & Son, Ltd.	LXXVIII
R. J. H. Tool & Equipment Co., Ltd.	XXXVI
Radio Heaters, Ltd.	LXXXIV
Ransomes, Sims & Jefferies, Ltd.	—
Ratcliffe, F. S., (Rochdale), Ltd.	—
Reavell & Co., Ltd.	LX
Redfern's Rubber Works, Ltd.	LXVI
Rediffusion, Ltd.	—
Reliance Gear & Eng. Co., (Salford), Ltd.	LXXXVI
Robertson Thain Ltd.	LXXVII
Rockwell Machine Tool Co., Ltd., The	—
Russell, S. & Sons, Ltd.	LVIII
Ryder, Thos. & Son, Ltd.	—
Scrivener, Arthur, Ltd.	—
Selson Machine Tool Co., Ltd.	XLVII
Service Electric Co., Ltd.	LXXXVI
Shell Mex & B.P., Ltd.	XI
Sieber, James, Equipment Co., Ltd.	LXXXII
Skinners (Redbridge), Ltd.	—
Smart & Brown Machine Tools, Ltd.	—
Snow & Co., Ltd.	—
Sparcatron	LXXIX
Sparklets, Ltd.	LXIV
Spencer & Halstead, Ltd.	XXXIX
Sternol, Ltd.	LXIV
Swift, Geo., & Sons, Ltd.	—
Sunbeam Anti-Corrosives, Ltd.	—
Sykes, W. E., Ltd.	LIII
Teleflex Products, Ltd.	—
Town, Frederick & Sons, Ltd.	—
Turner Machine Tools, Ltd.	LXXXIV
Udal, J. P.	LXXXVI
Unbrako Socket Screw Co., Ltd.	L
United Steel Companies, Ltd.	—
Universal Tools, Ltd.	LXII
Van Moppes & Sons (Diamond Tools), Ltd.	—
Vulcascot (Great Britain), Ltd.	LXXXVI
Wadkin, Ltd.	LXXII
Ward, H. W., & Co., Ltd.	XXIV
Ward, Thos. W., Ltd.	—
Westool, Ltd.	LXXXIII
Wickman, Ltd.	XVIII
Wicksteed, Chas. & Co., (1920), Ltd.	XXXVIII
Wild Barfield Electric Furnaces, Ltd.	—
Wolverhampton Die Casting Co., Ltd., The	LXXI
Yale & Towne Manufacturing Co., The	XXXII
Zinc Alloy Die Casters Association	—

All communications regarding advertisements should be addressed to the Advertising Managers, T. G. Scott & Son, Ltd. Crown House, 143-147, Regent Street, London, W.1. Phone: Regent 3891.
Printed by Maxwell, Love & Co. Ltd., White Lion Street, London, N.1.

nal

Page
Cover
xxv
xliv
—
lv
xlii
—
lxviii
lxxviii
xxxvi
lxxxiv
—
—
lx
lxvi
—
lxxxvi
lxxvii
—
lviii
—
—
xlvii
lxxxvi
xi
lxxxii
—
—
—
lxxix
lxiv
xxxix
lxiv
—
—
liii
—
—
xxxiv
xxxvi
l
—
lxii
—
xxxvi
lxxii
xxiv
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xxiii
xviii
xxviii
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lxxi
xxxii
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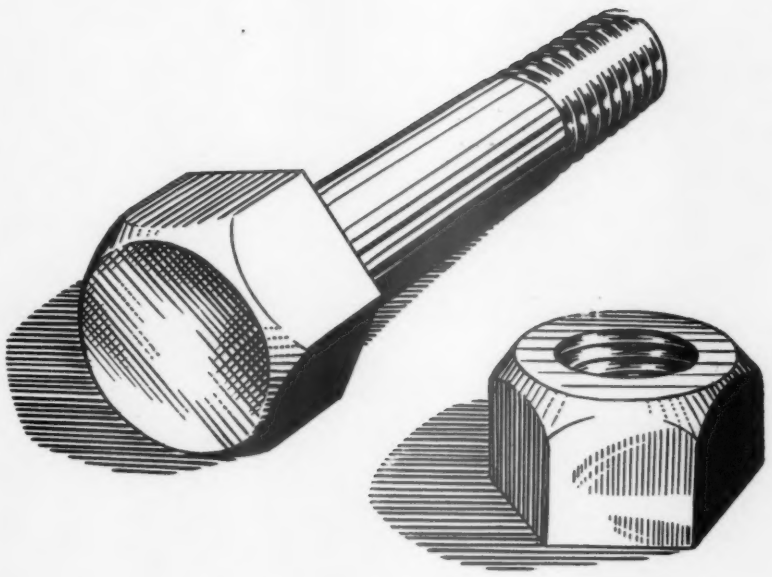
PARK GATE

QUALITY STEELS FOR NUTS & BOLTS



1825 EXPERIENTIA DOCET 1955

high tensile

steel bars

THE PARK GATE IRON & STEEL CO. LTD., ROTHERHAM

TELEPHONE: ROTHERHAM 2141 (10 lines)

TELEGRAMS: YORKSHIRE, PARKGATE, YORKS

Coventry Climax

Handling is a big part of the production picture :—

even with small parts *like these!*

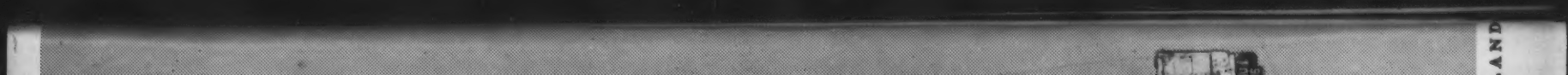
Acton Bolt Limited making 2,000,000 bolts a day by the most advanced methods cope with 12 tons of handling for every 1 ton of bolts despatched

Handling throughout this plant is by

Coventry Climax

fork lift trucks

COVENTRY CLIMAX ENGINES LTD. • (DEPT. J.P.) • COVENTRY • ENGLAND



JOURNAL SUPPLEMENT

Vol. 34, No. 5
MAY, 1955

INSTITUTION OF PRODUCTION ENGINEERS, 10, CHESTERFIELD ST., LONDON, W.1

The Automatic Factory:—

What does it mean?

Over 600 Conference bookings already received.

If you have not yet reserved your hotel accommodation at Margate, you are advised to do so without delay

NATIONAL CONFERENCE

MARGATE

16th—19th June 1955

An application form appears overleaf

THE INSTITUTION OF PRODUCTION ENGINEERS

CONFERENCE · MARGATE · 16th to 19th JUNE 1955

"The Automatic Factory—What Does it Mean?"

To: The Secretary,
Institution of Production Engineers,
10, Chesterfield Street,
London, W.1.

It is my intention to attend the Conference—*see note 4*

NAME..... **GRADE**.....

ADDRESS.....

FIRM & POSITION.....

***I shall be accompanied by my wife**
***I shall be accompanied by the following guest(s)** *see note 4*

1. Name .....

   Company or firm ..... Position held.....

2. Name .....

   Company or firm ..... Position held.....

3. Name .....

   Company or firm ..... Position held.....

I enclose remittance for Conference fees as follows:-

		£. s. d.
.....	Senior members at £5. 5. 0 each (See note 2 below)	.....
.....	Graduate members at £3. 3. 0 each	.....
.....	Student members at £2 2. 0 each	.....
.....	Ladies at £1 1. 0 each	.....
.....	Non-members at £8 8. 0 each	.....
	Total £	

Signed.....

NOTES:

1. *Delete where inapplicable.
2. Senior members are Hon. Members, Members, Associate Members, Associates, Representatives of Affiliated Firms.
3. Those attending the Conference are required to make their own hotel arrangements and a list of the hotels in Margate and district will be sent to all applicants. The Secretary is willing to reserve accommodation on behalf of applicants in accordance with their instructions.
4. Please give title (Mr., Mrs., etc.), honours and degrees for each person attending. Please use block letters throughout.
5. Cheques should be made payable to: "The Institution of Production Engineers".

MEETINGS

Visitors' tickets may be obtained from Section Honorary Secretaries.

MAY, 1955

BIRMINGHAM GRADUATE **7.0 p.m. MAY 10th**
The James Watt Memorial Institute, Great Charles Street, Birmingham.
"Efficient Production Methods Applied to Iron Founding" by G. W. Nicholls, M.I.B.F., A.M.I.Prod.E.

SHREWSBURY **7.30 p.m. MAY 25th**
Shrewsbury Technical College, Shrewsbury.
"Manufacture of Springs" by J. A. Roberts, M.Inst.B.E.

WOLVERHAMPTON **7.15 p.m. MAY 25th**
Wolverhampton & Staffordshire Technical College.
"Practical Approach to Engineering Fine Surfaces" by D. B. Ebsworth, A.M.I.Prod.E.

WOLVERHAMPTON GRADUATE
7.15 p.m. MAY 25th
Joint meeting with Wolverhampton Senior Section.
See above.

PRODUCTION APPOINTMENTS

BULLETIN No. 56
MAY 1955

The last date for receiving material for insertion in the following month's bulletin is the 20th of each month.

The fee for insertion of particulars regarding each appointment is £3 3s. (up to 100 words), and over 100 words £5 5s. A standard charge of £1 1s. per insertion is made to firms affiliated to the Institution, Technical Colleges, Universities and similar organisations.
Advertisers are advised that better response is likely if, in addition to essential qualifications, the following information is given:—

(*a*) Location of appointment; (*b*) Status in the organisation and scope of promotion; (*c*) Salary range and age range.

Advertisers are asked to advise the Institution when appointments are filled. The Institution reserves the right to refuse or withdraw any announcement and also to make any alteration in the wording to ensure conformity with the Institution standards. *Members interested in the following appointments should make application in accordance with the terms of notice. No correspondence can be undertaken by the Secretary other than the forwarding of replies to Box Nos.*

All advertisements appearing in this Bulletin are subject to the Notification of Vacancies Order of 1952.

Estimator Salesman required to take charge of newly established Sales Department covering gear production and machine tools. Applicants for this vacancy must have experience of gear manufacture and be acquainted with normal sales department technique. State full particulars of experience, age and salary required: Gear Grinding Co., Ltd., Shirley, Birmingham.

Senior Works Layout Engineers and Work Study Engineers. The English Electric Company at Stafford require engineers for the following posts: **Senior Works Layout Engineers** for work in light, medium and heavy electrical engineering manufacturing departments. Applicants should be well qualified in the requirements of process and plant layouts and have technical qualifications of at least O.N.C. standard and preferably be members of the Institution of Production Engineers. **Senior Work Study Engineers** for process and manufacturing development in light, medium and heavy electrical engineering. Applicants should have served a recognised apprenticeship and have a sound background of practical engineering in an appropriate manufacturing industry, together with technical qualifications to at least O.N.C. level. Applications, quoting reference 1225E should be addressed to: Dept. C.P.S., 336/7 Strand, London, W.C.2.

Planning Engineers. The English Electric Co. Ltd., Stevenage, have a number of vacancies at different levels for men with initiative, willing to tackle new and interesting processes, and development work, in the wide field of mechanical/electronic precision equipment. Qualifications looked for are:- 1. Higher National Certificate or equivalent, with a full apprenticeship. 2. Several years experience in methods and planning of mechanical/electronic assemblies, including the materials used. 3. Ability to clear technical snags during various stages of development. These are permanent staff positions, offering excellent prospects and conditions. Housing will be available to married applicants from the Greater London area. Applications to: Dept. C.P.S., 336/7 Strand, London, W.C.2. (quoting reference 900N).

Senior Planning Engineers are required by the English Electric Co. Ltd., commencing at Luton, transferring soon after to Stevenage. Applicants will have ample scope for reviewing designs for suitability of manufacture, advising the drawing office regarding choice of materials and achievable tolerances, and should have experience of assembly planning and tooling for small batch quantities of work ranging from light to medium mechanical and electrical engineering. Housing assistance will be available to successful candidates from the Greater London area, and those resident elsewhere can be considered. Applications, stating age, experience and qualifications should be addressed to: Dept. C.P.S., 336/7 Strand, London, W.C.2. (quoting reference 1360D).

Deputy Toolroom Superintendent. Hoover (Electric Motors) Limited, Cambuslang, Lanarkshire, have vacancy for a Deputy Toolroom Superintendent. Applicants must have a sound practical knowledge of toolroom work and have administrative experience suitable for a large toolroom associated with light electrical engineering. Range of work includes diecasting, single and multi-stage press tools, jigs and fixtures. Candidates should be holders of the Higher National Certificate in Mechanical or Production Engineering. Assistance will be given with housing. Applications, giving full details, should be made in writing to the Personnel Manager.

First-class Design Draughtsmen required for high production press tools, jigs, fixtures, etc., for valve and cathode ray tube components. Background of practical experience and O.N.C. least qualifications, but H.N.C. preferred. Experience in the use of tungsten carbide an advantage. Rates substantially above normal minimum for men of suitable experience. Five-day week, staff pension scheme, modern welfare amenities. Apply: Personnel Superintendent, The Edison Swan Electric Co. Ltd., Cosmos Works, Brimsdown, Enfield, Middlesex.

Special Purpose Machinery and Equipment Design Draughtsmen required. O.N.C. least qualification, but H.N.C. preferred. Men with imagination and initiative to develop original ideas with minimum direction. Basic applied electrical knowledge an advantage. Rates substantially above normal minimum for men with suitable experience. Five-day week, staff pension scheme, modern welfare amenities. Apply: Personnel Superintendent, The Edison Swan Electric Co. Ltd., Cosmos Works, Brimsdown, Enfield, Middlesex.

Engineers and Draughtsmen required. The Rootes Group Truck Plant, in the initial stages of an extensive expansion programme, invite applications for the following: Assembly Planning Engineers, Plant Layout Draughtsmen, Machine Shop Planning Engineers, Factory Layout and Materials Handling Draughtsmen (senior and junior). Please apply in writing to: the Secretarial Department, Commer Cars Limited, Biscot Road, Luton, Bedfordshire.

Deputy to the Director. An interesting professional appointment will shortly be made for the first time as Deputy to the Director of courses in advanced executive training and development in the London area. Applicants, who should be graduates with wide executive experience in industry and of about 40 years of age, must have good knowledge of more than one of the following fields: industrial engineering; industrial psychology; operational research and statistical work; work study and management training. The successful applicant will be required to assist in the preparation of courses in some of these subjects, as appropriate to his special experience, and to lecture on them; therefore, lecturing skill will be of importance. The salary will be of the order of £1,900 but for exceptional qualifications this is not an upper limit. Full details will be supplied to candidates whose preliminary application seems to be suitable. Apply to: Box No. 1080, I.Prod.E., 10 Chesterfield Street, London, W.1.

Method Study Engineer required by leading electrical transformer manufacturers in South London area. Must have a good basic engineering training, preferably H.N.C. standard, although a previous knowledge of method study or of transformers is not essential. Box No. 1081, I.Prod.E., 10 Chesterfield Street, London, W.1.

Assembly Methods Engineer required for electro-mechanical aircraft industry. Must have good knowledge of modern manufacturing techniques and shop methods. The position is superannuated and offers considerable scope to the man with adequate experience. Suitable applicant will have the opportunity of renting a modern house in the area of the New Town and preference will be given to a candidate who is registered on an approved housing list in the Greater London area. Applications should be made in writing, giving full particulars of qualifications and experience to: Personnel Manager, Rotax Limited, Maylands Avenue, Hemel Hempstead, Herts.

Qualified Engineers. Leading Management Consultants have several vacancies for qualified engineers with executive experience and with initiative to act as Consultants after training. Age not over 40. Salary scale £1,500 to over £2,000 per annum with considerable further prospects to exceptional men. Superannuation and expense allowances. Full details of qualifications and experience to: Box No. 1082, I.Prod.E., 10 Chesterfield Street, London, W.1.

Chief Production Engineer required by general engineering company employing 1,500 people. Applicants must have first-class experience in a modern engineering plant and be capable of the development and management of a Work Study department. Company's products are varied and range from medium sized fabricated plant to light machine and fitting work. The post is a responsible one and carries a commensurate salary together with excellent bonus and pension schemes. Write, stating age and full details of training and experience, together with salary required to: General Works Manager, The A.P.V. Company, Ltd., Manor Royal, Crawley, Sussex.

Assistant, aged 21 to 40 years, required for Laboratory and experimental Department, mainly on plastics—injection, extrusion and thermoset. Minimum standard, National Certificate—preferably in Chemistry: or Degree Physicist. Good prospects for keen and energetic man. Apply in writing to: T. H. & J. Daniels Limited, Stroud, os.

Sales Assistant required for Extrusion Machine Sales Division of well-known plastics machinery manufacturers in West of England. Must have good knowledge of extrusion process and be able to advise prospective customers. Good prospects for energetic and qualified man. Apply first in writing to: Box No. 1083, I.Prod.E., 10 Chesterfield Street, London, W.1.

Production Controller, Senior Progress Engineers. The Aircraft Division of the Bristol Aeroplane Company have the following vacancies:- **Production Controller** for which applicants must have served an engineering apprenticeship, be fully experienced in all aspects of production control as applied to modern aircraft manufacture; and be capable administrators. **Senior Progress Engineers.** An engineering apprenticeship, and experience in aircraft production control and progress procedures are necessary qualifications. Applications, quoting **AIR.16** should give full details of education, qualifications and experience, and be addressed to: the Personnel Manager, The Bristol Aeroplane Co. Ltd., Aircraft Division, Filton House, Bristol.

Planning Officer required by food manufacturer to take charge of production planning and progressing at their Central London factory. Previous experience of production planning is essential and a knowledge of large-scale meat processing would be of great advantage. The position is permanent and pensionable and full staff facilities are available. Salary dependent upon age, qualifications and experience with a minimum of £900 per annum. Applicants should write, giving details of education, age and experience to: Box No. 1084, I.Prod.E., 10 Chesterfield Street, London, W.1.

Senior Designers, required for interesting work on special purpose machines, press tools, jigs and fixtures, in a newly opened office in the City area, London, E.C.1. This office is part of a development programme of an established engineering company and salaries of £700 upwards, and monthly staff appointments are available to qualified designers. Write: Box No. 1085, I.Prod.E., 10 Chesterfield Street, London, W.1.

Junior Development Engineer. Venesta Limited require a Junior Development Engineer for their Collapsible Tube Factory at Silvertown for work connected with process and product development. Candidates should be about 25 years of age, have served a good engineering apprenticeship and preferably possess Higher National Certificate in Mechanical Engineering. Salary scale £600 - £720. The starting salary within this grade will be according to qualifications and experience. Applications should include full details of qualifications and experience and be addressed to: the Personnel Manager, Venesta Limited, North Woolwich Road, London, E.16.

Production Consultants. Noel Clark & Partners Limited, Management Production & Cost Consultants, 436 Grand Buildings, Trafalgar Square, London, W.C.2, have one immediate vacancy for a Production Consultant and another in September. Engineering apprenticeship, A.M.I.Mech.E., or A.M.I.Prod.E., and four years senior production experience essential. Age 28 to 40. Required to initiate bonus incentives based on time and motion study, rating synthetics, and production control. Assignments only in U.K. senior managerial salary, plus allowances. Please write, giving full details of qualifications and experience.

Managing Director required for Australian subsidiary of large U.K. group of companies. The position is a sound and progressive one. Applicants of proven experience in the administration of both production and commercial aspects of light engineering industry should write in confidence to: Box No. 1086, I.Prod.E., 10 Chesterfield Street, London, W.1.

Assistant Works Manager, aged 28 - 38, required by leading precision instrument manufacturing company with modern factory in Kent. Applicant should have good shop floor experience mainly on light assembly and finishing, ability to organise and control approximately 100 employees, to introduce through foremen improved manufacturing methods, to operate production programmes and to maintain discipline. Successful applicant will be eligible for rapid promotion. Starting salary about £1,000 per annum, according to qualifications. Contributory pension scheme. Reply, stating age, education, previous earnings and positions held, in confidence to: Box No. 1087, I.Prod.E., 10 Chesterfield Street, London, W.1.

Development Engineer. Connollys (Blackley) Ltd., invite applications from corporate members of the Institution of Mechanical Engineers or its equivalent to carry out development into new methods of manufacturing insulated winding wire. Originality of thought, wide imagination and workshop experience essential. Preferred age about 30. Salary around £1,000 per annum. Applications to: the Director, Connollys (Blackley) Ltd., Kirkby Industrial Estate, Liverpool.

Assistant Production Manager is required for a Brass Rolling Mill and Melting Shop (North East Coast). Candidates should have good knowledge of modern equipment for production of sheet and strip. Salary dependent on qualifications. Applicants should give fullest details in confidence, with copies of references. Write: Box No. 1088, I.Prod.E., 10 Chesterfield Street, London, W.1.

Work Study Engineer, fully experienced, to take charge of Ratefixing Department in modern engineering works, on shift work, 30 miles north of London. Applicants must be experienced in machining and assembly of automobile products. Salary £900 - £1,000 and prospects for a keen ambitious man with the requisite experience. Housing facilities available. Box No. 1089, I.Prod.E., 10 Chesterfield Street, London, W.1.

Production Planning Engineers. Standard Telephones & Cables Ltd., and Kolster-Brandes Limited, Sidcup, Kent, require Production Planning Engineers, aged 22 - 35, for these progressive and pensionable posts:- 1. **K.B. Radio/T.V. Factory.** (a) B.Sc.(Mech.) or H.N.C.(Mech.) and trade apprenticeship, with experience of light engineering assembly, jigs, fixtures, etc. Some experience of work study desirable. (b) H.N.C.(Mech.) and trade apprenticeship for trainee post. Production Planning experience not essential. 2. **Brimar Valve & C.R.T. Factory — (2 posts).** H.N.C. and trade apprenticeship, preferably with experience of C.R.T. and Radio Valve manufacture. Write, with brief details of qualifications and experience to: W. J. Yeomans, Personnel Manager.

Chief Production Engineer required immediately by medium sized mechanical and electrical manufacturing company in South West London. Product range includes radio and television components and equipment, domestic appliances and tape recorders. Substantial salary and interesting and assured future for the right man. Box No. 1090, I.Prod.E., 10 Chesterfield Street, London, W.1.

Production Engineers. F. Perkins Limited, Peterborough, have openings on their technical staff for production engineers to be engaged on material handling problems. These vacancies are particularly suitable for young engineers in their early twenties who possess at least the O.N.C. and good industrial training, preferably related to quantity production. Positions are permanent and offer attractive prospects and experience to first-class men. Please apply, in confidence, stating age, experience and education in chronological order to: Personnel Manager, F. Perkins Ltd., Eastfield Factory. Peterborough.

Senior Planning Engineers required for Oil Engine Division, comprehensive experience on quantity production and knowledge of jig and tool design essential. Modern factory, pension scheme, good salaries for experienced men. Write, giving age, details of qualifications and experience to: Labour Manager (X), Rolls-Royce Ltd., P.O. Box 31, Derby.

First-class Ratefixers and Estimators required for diesel engine work in modern factory in Midlands. Applicants should possess sound knowledge of quantity production by modern methods. Excellent conditions, pension scheme, good salary for keen experienced men. Write, giving age, details of qualifications and experience to: Labour Manager (R), Rolls-Royce Ltd., P.O. Box 31, Derby.

Chief Production Engineer required by a large company making a wide range of products, but primarily concerned with the manufacture of domestic electrical appliances and heavy duty canteen equipment. This factory is situated in a rural area outside the potteries. A wide experience in production engineering and planning is essential and preference will be given to those with academic qualifications such as Higher National Certificate, etc. This appointment is permanent and pensionable. Salary will be commensurate with experience and qualifications. Would applicants please apply, giving full details of age, education qualifications, practical experience and list of appointments held, in chronological order, to: Managing Director, Simplex Electric Co. Ltd., Creda Works, Blythe Bridge, near Stoke-on-Trent.

Production Controller required for brake lining and textile manufacture. Applicants should be between the ages of 33 and 45 and preferably have a university education with subsequent engineering training and executive experience. Practical knowledge of production and material control and allied functions is essential, and some experience of management problems desirable. This is a senior appointment and will carry a four-figure salary. Applications, giving details of age, education, experience and qualifications to: the Secretary, Small & Parkes Ltd., Hendham Vale Works, Manchester 9.

Personal Assistant — age 25 - 35 years — required by Managing Director of firm manufacturing small to medium sized automatic boilers in Surrey. Loyalty and initiative, coupled with good technical training and works experience essential. Excellent prospects for the right man. Send full particulars to: Box No. 1091, I.Prod.E., 10 Chesterfield Street, London, W.1.

Director of Personnel required by Industrial Corporation employing large number of high grade university staff. Graduate or equivalent, age 35 to 40. Knowledge of modern recruitment and selection procedures and experience in handling top executive staff essential. Apply in confidence, stating age and full particulars of education, training and experience, in chronological order, with salaries to: Box No. 1092, I.Prod.E., 10 Chesterfield Street, London, W.1.

Chief Engineer required by well-known food manufacturing company in North of England. Qualifications, A.M.I.Prod.E. with lengthy experience of plant and equipment used in preserves and canning business. Capable of undertaking complete new factory layouts. Pension scheme. Removal expenses paid. Apply, stating salary to: Box No. 1093, I.Prod.E., 10 Chesterfield Street, London, W.1.

Work Study. Expanding cosmetics company in South West London are introducing work study and have a vacancy for a trainee in all aspects of this work. Suitable for either man or woman. Please give details of age, career to date, and present salary. Box No. 1094, I.Prod.E., 10 Chesterfield Street, London, W.1.

Technical Assistant to the Chief Engineer required at their head office in Central London by leading light engineering company engaged in the manufacture of calculating machines. The appointment will be mainly administrative and will involve liaison with outside suppliers, therefore, experience in discussing technical problems at high level will be an advantage. Applicants should be between 30 and 45 years of age and must possess a sound knowledge of press work and tool making to very close limits. Some experience with automatic screw machines is also a desirable qualification. Commencing salary £750 - £900 per annum, according to age and experience, with excellent prospects of future advancement. Pension

scheme. Write, giving full personal details, in confidence, to: Felt & Tarrant, Ltd. (Comptometer Adding and Calculating Machines), Aldwych House, Aldwych, London, W.C.2. Mark envelope "Technical Assistant" and "Confidential".

Shift Superintendent is required by Chappie Limited, manufacturers of canned animal foods. There are four Shift Superintendents, who report directly to the Production Manager and are each responsible to him for the entire output of the Company's products during his shift, with full responsibility for quality, quantity and costs. The four Shift Superintendents in the production division as a team give complete twenty-four hour coverage, seven days a week. Applications are invited from graduate engineers (mechanical preferred) between 28 and 35 years of age. Production experience in a supervisory rôle is essential. Experience of line production (canning or similar) is desirable although not essential. The commencing salary will be not less than £1,500 per year with good prospects of a higher salary with experience and plus a non-contributory pension scheme, life assurance, sickness and other benefits. Further particulars and official application forms will be sent to potential candidates on request, by the Personnel Officer, Chappie Limited, Melton Mowbray, Leicestershire.

Production Planning Engineer required by growing company having products covering wide range of machining, fabrication, painting and assembly. Must be experienced and competent in all branches of production engineering including modern factory methods, planning, jig and tool design, progress. Knowledge of materials handling an advantage. Company situated in pleasant country district one hour West of London. Canteen facilities. Please write, giving age, past experience, married/single, present salary, to: Box No. 1095, I.Prod.E., 10 Chesterfield Street, London, W.1.

Chief Draughtsman required to take charge of contract drawing office in London area. Must have experience of special purpose machine design, jig and tool design, and be a good general mechanical designer and able to control staff. Salary approximately £1,000 per annum. Box No. 1096, I.Prod.E., 10 Chesterfield Street, London, W.1.

Planning Engineers. Applications are invited for posts as Planning Engineers with an engineering company in North London. The work entails responsibility for methods and process planning on a wide range of light/medium mechanical engineering products manufactured by line and batch production methods. Applicants should have methods and process planning experience on similar work, and possess a good general mechanical engineering background. Preference will be given to applicants with wide machine shop experience, particularly on capstan and automatic work. The company offers excellent salaries and prospects for advancement together with ideal welfare facilities including a pension scheme. For people joining the company from outside the North London area, it is of interest that the Works is within easy travelling distance of North London residential areas verging on the green belt of Middlesex and Hertfordshire and of Epping Forest. Full assistance towards the purchase of houses will be given to selected applicants and removal and legal expenses paid. Applications, giving full details of age, experience, qualification and salary required to: Personnel Manager, British Oxygen Engineering Limited, Angel Road, Upper Edmonton, London, N.18.

Planning Engineer with experience in aspects of coil winding applicable to radio and television. The post offers good scope to applicants with initiative and drive, and the commencing salary would be of the order of £600 per annum upwards, according to experience. Apply in writing in the first instance, giving full details of experience to: Personnel Department, (P.E.) Murphy Radio, Welwyn Garden City, Herts.

Assistant Works Manager for factory in New Zealand. Production Engineer required to assist in the control of an old established firm manufacturing domestic electric cookers and solid fuel appliances. (The firm is a member of the Radiation group of companies.) Works comprise foundry, machine and press shops, painting, polishing, vitreous enamelling and assembly. Applicants should have experience of modern flow production methods as well as proved administrative ability. Excellent prospects for promotion. Age preferred 30 - 40. Salary in accordance with experience but not less than £1,200 per annum. Applications, which will be treated in the strictest confidence, should give full details of career. Box No. 1097, I. Prod.E., 10 Chesterfield Street, London, W.1.

Jig and Tool Draughtsman. The North British Steel Foundry Ltd., Bathgate, invite applications for the above position. The post has prospects for development and should be of immediate appeal to a young draughtsman, not over 30, who is capable of independent thought. Applicants should have experience of medium machine tools and technical qualifications to at least O.N.C. level. Pension scheme is in operation. Apply with full details, age, experience, qualifications, present salary, etc., to: The Works Manager.

Qualified Engineering Staff. Attractive opportunities offered to experienced men with imagination and ability to advance with expanding organisation. International Company producing automotive transmissions. Modern factory, Hertfordshire: Welfare and superannuation schemes. Experience in automotive gear design would be an asset. **1M. Project Engineers, 2M. Section Leaders (Design), 3M. Design Draughtsmen, 4M. Junior Draughtsmen.** Applications stating age, marital status, qualifications, availability and present salary, quoting appropriate reference number to: Box No. 1098, I.Prod.E., 10 Chesterfield Street, London, W.1.

Qualified Engineering Staff. Attractive opportunities offered to experienced men with imagination and ability to advance with expanding organisation. International Company producing automotive transmissions. Modern factory, Hertfordshire: Welfare and superannuation schemes. Experience in multi-machines and line production would be an asset: **5L. Production Engineers, 6L. Materials Controller, 7L. Plant Layout Draughtsmen, 8L. Planning and Process Engineers.** Applications stating age, marital status, qualifications, availability and present salary, quoting appropriate reference number to: Box No. 1099, I.Prod.E., 10 Chesterfield Street, London, W.1.

Purchase Manager, required by International organisation specialising in automotive transmissions. Excellent opportunity for present assistant Chief Buyer with automobile experience to carry full responsibility. Modern factory, Hertfordshire: Superannuation, welfare schemes. Applications stating age, marital status, qualifications, availability and present salary to: Box No. 1100, I. Prod. E., 10 Chesterfield Street, London, W.1.

Chief Inspector fully experienced in mass production of automotive transmissions required by International organisation. Ability to organise and control inspectorate staff and set quality standards. Excellent opportunity for person with experience plus imagination to advance with team of keen executives. Modern factory, Hertfordshire: Superannuation, welfare shemes. Applications stating age, marital status, qualifications, availability and present salary to: Box No. 1101, I.Prod.E., 10 Chesterfield Street, London, W.1.

Production and Development Engineers. The Glacier Metal Co., Ltd., Kilmarnock, urgently require additional Production and Development Engineers to meet the demands of an expanding factory and an intensive development programme. We are specialists in the production of plain bearings, but their manufacture throws up many engineering problems of a general nature. We therefore require qualified engineers who have alert and enquiring minds to investigate production methods and assist with the development and introduction of new processes. The work is extremely interesting and offers exceptional opportunities for making contact with a wide range of engineering, metallurgical and managerial activity. We are prepared to pay generous salaries to the right kind of men and there are excellent

opportunities for further advancement. The factory is a modern one (situated close to the Ayrshire coast.) Working conditions are congenial, and staff bonus and pension schemes are in operation. Some assistance may be given with housing. Applications, please to: the Personnel Manager.

Top Level Production Executive and Chief Development Engineer. Black & Decker Limited, Harmondsworth, Middlesex, has been endeavouring to fill two important executive positions. All applicants so far have failed to meet the qualifications which the company feel essential in the discharge of responsibilities of these posts: qualifications are not only of technical and administrative ability, but, above all, of personality. For guidance of future applicants, the posts to be filled are as follows:- (a) **Top level production executive** with up-to-date manufacturing experience and the supporting technical background to control and to co-ordinate all the manufacturing operations of a light engineering works. The duties and responsibilities also embrace the functions of work study, jig and tool design, plant layout, process methods and production control. (b) **Chief Development Engineer** with high technical education and wide experience in the light engineering field, with the drive, enthusiasm and inspiration to seek out new developments and the ability to marshal them through to final manufacturing stage. Both these positions form part of a progressive and expanding organisation, and applicants who feel qualified to fill either, must be capable of commanding a salary of £4,000 per annum. Applications, which should be in writing in the first instance, to: Personnel Department.

Engineers who are or have been employed by Industrial Consultants or have had equivalent production experience and who possess a university degree, are invited to apply for a position on the senior production staff of a well known engineering company in the Midlands. The salary offered will be commensurate with the qualifications of the candidate but will be of the order of £1,500 to £2,250 per annum. Age 30 - 42. There is an excellent contributory superannuation scheme and the successful candidate will have the opportunity to rise to the higher management of the company within a few years. All applications will be treated in the strictest of confidence and should state age and include a brief description of the applicant's qualifications and experience. Box No. 1102, I.Prod.E., 10 Chesterfield Street, London, W.1.

Keen Mechanical Engineer with character and initiative required by well-known and old-established Company. Age 30 - 35, must have served apprenticeship and be a first-class engineer of proved ability, with practical experience in small quantity mass production, to take charge ultimately of small modern Works of 70 in country. The position is permanent and holds outstanding possibilities for advancement for keen and progressive man. Commencing salary £1,000 per annum. Write in confidence, giving full particulars of experience, age, positions held, etc., to: Box No. 1103, I.Prod.E., 10 Chesterfield Street, London, W.1.

Qualified Works Manager. Commer Cars Limited require a fully qualified Works Manager to take charge of machine and assembly plants at Luton and Dunstable, employing over 2,000: a unique opportunity for advancement within the Rootes Group. Please reply, giving fullest details of experience to: the Managing Director, Commer Cars Limited, Luton.

Box Nos. 1022 and 1058. The advertisers wish to thank all applicants for these vacancies which have now been filled.

EDUCATIONAL APPOINTMENTS

National College of Horology and Instrument Technology, Northampton Polytechnic, St. John Street, London, E.C.1.

Head of the National College of Horology and Instrument Technology. The Minister of Education, in consultation with the Board of Governors, proposes to fill a vacancy, as from 1st September, 1955, for a Head of the National College of Horology and Instrument Technology. The College is accommodated at the Northampton Polytechnic, St. John Street, London, E.C.1. The College provides for technical education and research to the highest levels in connection with the horological and the instrument making industries. The curriculum includes a three-year Diploma course in Horology. Advanced courses in Instrument Technology are projected for next session. Candidates for the post must have good academic qualifications and industrial experience. Salary scale £1,265 by increments of £50 a year to £1,415 per annum. The post is recognised for pension purposes under the Teachers' Superannuation Acts. A letter of application to include particulars of age, academic qualifications, industrial experience, and the names of three persons to whom reference may be made, should be sent to: the Secretary, National College of Horology and Instrument Technology, Northampton Polytechnic, St. John Street, London, E.C.1.

Central College of Further Education, Barrow-in-Furness. Full-time Assistant Grade A. Required in September, 1955, a full-time Assistant, Grade A, to teach machine shop engineering and ancillary subjects to Final City and Guilds standard. Applicants should possess sound technological qualifications and good industrial experience. Burnham Scale, viz., £450 by £18 to £725 with additions in respect of approved qualifications and training and for suitable industrial and teaching experience. Application forms, obtainable by sending a stamped addressed foolscap envelope to: the Chief Education Officer, John Whinnerah Institute, Barrow-in-Furness, should be returned as soon as possible.

Mining and Technical College, Church Street, Barnsley. Required for September 1955:- **Senior Lecturer** in Mechanical Engineering for courses of Higher and Post Higher National Certificate standard. Salary:- £1,065 by £25 to £1,215 per annum. **Lecturer** to teach Mechanical Engineering subjects to Ordinary and Higher National Certificate level. Salary:- £965 by £25 to £1,056 per annum. Candidates for each of the above posts should possess a degree in Mechanical Engineering and have had appropriate industrial and teaching experience. **Assistant Grade A** to teach Workshop Practice and engineering subjects in Ordinary National Certificate and City and Guilds courses. Candidates should hold the Higher National Certificate in Mechanical (or Production) Engineering and/or the final certificate of the C.G.L.I. in Machine Shop Engineering. Salary £450 by £18 to £725 per annum, plus increments for approved industrial experience. Application forms obtainable from the Principal, Mining and Technical College, Church Street, Barnsley, and should be returned as soon as possible.